COMPARATIVE ANALYSIS OF BIOSURVEILLANCE METHODOLOGIES

THESIS

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Abstract

Threats of Chemical, Biological, Nuclear, Radiological, or High Yield Explosive (CBRNE) events in the United States have caused the implementation of improved preparedness initiatives. This paper focuses on *biological* readiness initiatives, and compares two methodologies; one already fielded called BioWatch and another developing project, called "A Hot Idea."

BioWatch, a biosurveillance methodology operating since June 2003, collects air samples in 31 cities across the United States on filter paper that is analyzed for the presence of harmful biological agents. The time from biological release until emergency response actions are initiated is expected to be 27-36 hours.

"A Hot Idea" uses the body's immune response to identify the presence of harmful biological agents. An increase in temperature is the body's response to inoculation with a foreign agent. Detecting a temperature increase, using infrared thermographers, in a statistically significant portion of population would allow earlier identification of a biological release and thereby accelerate initiation of response actions. A selected population including policemen, firemen, and postal carriers, will be monitored for elevations in temperature above previously developed individual temperature profiles. These "monitors" have traceable routes to identify clustering of temperature elevations and allow delineation of the geographic area of exposure.

The two methodologies were compared using a Benefit-Cost analysis. Benefit was defined as the "costs averted" minus the cost to provide surveillance, and was based

upon the reduction in mortality expected with each methodology. Advantages and disadvantages of each system, and areas needing better delineation were discussed. Significant challenges were identified with each methodology.

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David M. Kempisty

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COMPARATIVE ANALYSIS OF BIOSURVEILLANCE METHODOLOGIES

Chapter 1 - Introduction

From historic times through present day, biological agents have had dramatic impacts on the human race. The Peloponnesian War in 431 B.C. involved an epidemic which killed thousands of Athenians and was attributed to poisoning of the water wells by the forces of Sparta (Warner, 1972). In 190 B.C., Hannibal, the leader of the Carthagian Army, used biology to his advantage by placing poisonous snakes inside clay pots that were launched onto enemy vessels where the pots broke and released their unwanted contents (Christopher, 1997). In 1346, Mongolian forces catapulted plague infested cadavers over the fortress walls of Kaffa, the city they were attacking. The virulent bacteria was successful in finding new hosts inside Kaffa and, as a port town, plague-infested rats soon spread the bacteria to other ports throughout Europe. Pandemic outbreaks of plague followed and the term "Black Death" is commonly used to describe the events. Taking the lives of over 1/3 of the population of Europe, the Black Death is estimated to have killed 25 million people (Jackson, 2003). The Black Death had significant impact on the development of medieval Europe and resulted in the period of time referred to as the "Dark Ages."

More recently, the Spanish Influenza pandemic of 1918 took more than 20 million lives (Gensheimer, 2003). The virulence of the agent was great: it took a similar number of lives as WWI but in 1/5th the time (van Hartesveldt, 1992). Both today and in the future, biological agents affect our everyday lives. Natural and malicious use of

microorganisms is inevitable. Obvious agents in our generation include Human Immunodeficiency Virus (HIV), West Nile Virus, seasonal influenza, avian influenza, and the coronavirus that causes Severe Acute Respiratory Syndrome (SARS). New agents are emerging each year. Our country's preparedness needs to be evaluated and improved to minimize the effects of the next major biological event when it occurs.

The United States government currently performs biosurveillance every day with a biodefense initiative called BioWatch. An early-warning surveillance system, BioWatch is designed to detect a release of a harmful biological agent in major cities across the United States. The implementation of the BioWatch system is a step forward; it improves readiness posture against harmful biological agents. However, there are shortfalls to the program. Rarely is a panacea identified providing comprehensive solutions to all aspects of a complex problem and BioWatch is no different.

This thesis will explore an alternative solution to BioWatch, focusing on one in particular, that harnesses the human body's immune system as its warning signal. This alternative involves regularly scheduled thermal infrared scanning of a portion of society. Core temperatures would be tracked and a pre-determined variation will signal as a possible exposure to a harmful biological agent. This alternative technology is referred to as "A Hot Idea" and is credited to Dr. Robert Armstrong of the Center for Technology and National Security Policy at the National Defense University and Dr. Stephen Prior of the National Security Health Policy Center at the Potomac Institute for Policy Studies. The complete name of Drs. Armstrong's and Prior's methodology is "Rapid Detection of

Exposure to Potentially Harmful Materials" but hereafter will simply be referred to as "A Hot Idea." This thesis presents a comprehensive comparison between the two biological agent surveillance alternatives. A benefit-cost model was developed to compare the two technologies from an economic standpoint. Additionally, thorough discussion of intangible factors not represented in the model and other alternative biological surveillance strategies is undertaken.

BioWatch Background

The Public Health Security and Bioterrorism Preparedness and Response Act of 2002 (more commonly referred to as the "Bioterrorism Act") was passed as Public Law 107-188 on 12 June 2002 to improve the country's bioterrorist readiness. Since that time, The Department of Health and Human Services (HHS) has funded over $2.7 billion for public health preparedness efforts through grants administered by the Center for Disease Control and Prevention (CDC) and just over $1 billion for hospital preparedness grants administered by the Health Resources and Services Administration (Schuler, 2004). Table 1 shows the major public health information technology initiatives undertaken to address concerns that generated the Bioterrorism Act. BioWatch is a subset of the Department of Homeland Security's (DHS) Biological Warning and Incident Characterization System.

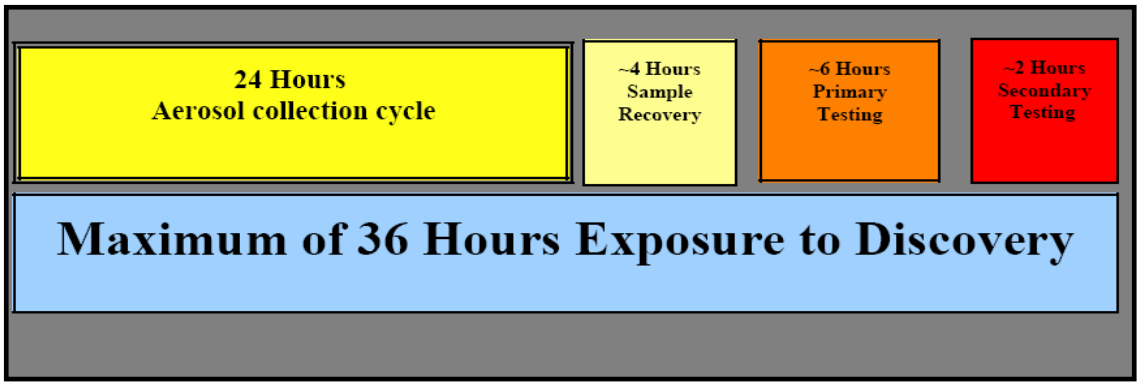
Table 1- Major Federal Public Health Information Initiatives in Response to the Bioterrorism Act of 2002 (http://www.dhs.gov/dhspublic/).

Major Federal Public Health IT Initiatives	
Initiative	**Description**
CDC	
Public Health Information Network	A national initiative to implement a multiorganizational business and technical architecture and associated information systems.
DHS	
Biological Warning and Incident Characterization System	An initiative to integrate data from environmental monitoring and health surveillance systems to provide warning of a biological attack and to help guide an effective response.
National Biosurveillance Integration System	An effort to combine federal medical, environmental, agricultural, and intelligence data to allow early detection of events and assist response.

During the 2003 State of the Union address, President George W. Bush announced that the federal government was "deploying the nation's first early warning network of sensors to detect biological attack." (Bush, State of the Union Address, 2003). He was referring to BioWatch.

Although overseen and funded by DHS, many organizations implement BioWatch. In coordination with the Environmental Protection Agency (EPA), the CDC and their members of the Laboratory Response Network (LRN), BioWatch provides early-warning surveillance for pathogenic agents at various cities around the country. The LRN is network of certified laboratories created to improve the nation’s public health laboratory infrastructure in both capability and capacity (CDC website, 2005). BioWatch is designed to detect and confirm the presence of biological agents within 36 hours of a release as shown in Table 2.

Table 2 - BioWatch Detection and Confirmation Timeline (Emory, 2005)



The sampling collection details are performed by the EPA. These duties are well-suited to the EPA as the BioWatch air samplers are similar to, and sometimes co-located with the agency's air quality monitors. The analysis component of the program is overseen by the CDC. The actual analysis is performed by members of the LRN. Finally, in the case of a positive identification of a harmful biological agent, the Federal Bureau of Investigation (F.B.I) has lead jurisdiction (Shea, 2003).

Specific details regarding the schedule of sample collection and analysis, the particular agents analyzed for, and the location of detectors is understandably guarded for security reasons. Sources report that BioWatch was unveiled in June 2003 and involves approximately five hundred air samplers in thirty-one cities that continuously collect air samples that are retrieved every twelve hours and analyzed for harmful biological agents (Kosal, 2003)[1]. An analyst from the Congressional Research Service in the Library of Congress, Dana Shea, suggests, "The system tests for the pathogens that cause anthrax, smallpox, plague, and tularemia but the entire list of pathogens is not publicly available"

[1] Sources report this collection time to vary between 12 and 24 hours depending upon the perceived threat and location. Table 1.1 is taken from the Emory's Inspector General report and states the *maximum* collection time to be 24 hours.

(Shea, 2003). Government officials have indicated that the number of agents tested for is less than a dozen (Prior, 2004). Although the exact number of agents tested for is unknown, the number is certainly finite. It is likely that the six Category A agents identified by the CDC are tested for: anthrax, smallpox, tularemia, botulinum toxin, plague and agents that responsible for viral hemorrhagic fevers (CDC website, 2005). Definitions for the categories created by the CDC are described in Table 3 below.

Table 3 - Biological agents as categorized by the Center for Disease Control and Prevention (CDC website, 2005)

CATEGORY	DEFINITION	EXAMPLE
A	Easily disseminated or transmitted from person to person, cause high mortality rates, and have the potential to disrupt both public health and social life	Anthrax, Smallpox, Tularemia, Plague, Botulinum Toxin
B	Moderate in ease of dissemination and morbidity with a low mortality rate.	Cryptosporidium, West Nile virus
C	Potential for high morbidity and mortality rates and can cause major health impact	Rabies, Influenza

Regarding specific cities participating in the program, Shea reports Philadelphia, New York City, Washington, DC, San Diego, Boston, Chicago, San Francisco, St. Louis, Houston, and Los Angeles are all members of the surveillance effort (Shea, 2003).

Thermal Scanning Background

The cornerstone of "A Hot Idea" is to recognize a signal, namely an elevation in body temperature, after the human body is introduced to a foreign biological agent. The human body and its immune system sample the environment with every breath of air. Triggers to the immune system are automatic with the introduction of a foreign biological agent. Sneezing and coughing initially attempt to physically remove the foreign agent. If

needed, antibodies are produced and core temperatures are elevated as the body's metabolic rate is increased to assist in the removal of the foreign agent. It is the body's response of increasing the metabolic rate and consequently elevating the body's temperature that is key to "A Hot Idea." The response time and degree of temperature elevation vary depending upon the concentration and type of infectious agent the immune system is dealing with, but generally speaking, an increase will occur before an individual knows their body has been attacked by a biological agent. Working with the workforce of a particular city, individual temperature profiles would be developed and monitored. This workforce represents a group of "mobile samplers." As an example, the Washington D.C. workforce handling emergency response and postal duties consists of approximately 23,500 personnel (Armstrong, 2004). Police comprise the majority of this workforce with 12,110 personnel. The rest of the workforce includes 150 parking enforcement workers, 4,900 firefighters, 5,940 mail carriers and 400 emergency medical service workers (Armstrong, 2004). This workforce has a traceable daily route. The workers' core temperatures will be collected pre- and post- work shifts. If one member's core temperature varies significantly from a baseline temperature that has been established specifically for that individual, that person will be notified that he or she may be acquiring an illness – but work will continue as usual. But, for example, if a predetermined statistically significant portion of individuals report temperatures abnormally above their specific temperature profiles, data management software will notify personnel of this anomaly. Further investigation would be undertaken to determine the areas visited that day by the affected personnel and identify the source causing the elevation in temperature.

One quick, non-invasive method of measuring body temperature utilizes an infrared thermal scan. This approach was applied in airports in Singapore, Tokyo, Hong Kong, and Canada during the SARS epidemic of 2003 (Shea, 2003). In Canada, 763,082 arriving and departing people were scanned by thermal scanners sensing body temperatures greater than 38°C (St. John, 2005). A Beijing report states that 30 million people were scanned for elevated temperatures during a 6 month period; 9,292 of these people were pulled aside to further investigate if personnel suffered from SARS. Of these personnel, 38 were suspected SARS and 21 were confirmed SARS cases (Wu, 2004). "A Hot Idea" will subject a segment of a city's workforce to similar infrared thermal scans looking for clusters of workers with elevated temperatures. These clusters would then undergo additional medical screening to identify the source of increased temperature.

Identifying the cause of the elevation in temperature will elucidate the responsible agent. This will be true whether the agent is a Category A agent, an emerging infectious disease not yet identified, or a simple seasonal influenza virus. BioWatch, on the other hand, will only notify personnel of the presence of a harmful agent if it is selectively screened for. Dr. Stephen Prior, the Director for the National Security Health Policy Center of The Potomac Institute for Policy Studies, suggests the number of agents screened for is somewhere between 6 and 12 agents (Prior, 2004).

The sensor used in “A Hot Idea” is uniquely selective to agents that will affect the human body. This is true because the sensor *is* the human body. Essentially, false positive results are eliminated: anything that causes a response in the mobile sensor, or the workforce, will cause a similar response in the human body because they are one and the same. Conversely, it could be argued that there is value in notification of, for example, a botched anthrax release. If all the spores released in a bioterrorism event were too large to affect the human body (effectively removed by coughing and sneezing), there is still value in knowing there was an unsuccessful bioterrorist event. “A Hot Idea” wouldn’t alert officials of this unsuccessful malicious release of biological agents, while the BioWatch analysis might.

By attempting to identify the causative agents of disease, “A Hot Idea” will identify both intentional releases of biological warfare agents and natural outbreaks of disease. For example, the onset of the seasonal influenza or an emerging unknown infectious disease may be identified. Both will most likely be natural outbreaks evading detection of the BioWatch system. Advantages to positively identifying the onset of seasonal influenza include implementing final public health readiness issues, checking the viability of the current year’s vaccine, and commencement of educational and public awareness initiatives. Advantages to positively identifying possible pandemic strains of influenza, such as avian influenza (“H5N1”) are many and discussed in an upcoming section.

The location of samplers deserves consideration for "A Hot Idea" and BioWatch. Optimal placement of sampling equipment must be determined with the fixed BioWatch samplers. The changing environmental conditions and the sometimes-strange interaction between high-rise buildings and winds present challenges to finding the optimal location to sample. The workers of "A Hot Idea" on the other hand, travel traceable routes including exposure to both indoor and outdoor environments. The workers thereby cover a greater geographical area than a number of stationary samplers. If a cluster of workers shows abnormally high core temperatures, an investigation could be undertaken identifying the similar locations visited by those affected. Conversely, in areas with large crowd densities such as stadium events and heads of states gatherings, stationary samplers could be brought in sample the atmosphere individuals are exposed to. In this scenario, both methodologies might be considered for implementation

Methodology

BioWatch and "A Hot Idea" are compared and contrasted against each other and against the idea of a "do-nothing" approach. This research determines a benefit – cost relationship between two different detection methodologies. Aspects other than economic are also considered. The principal goal listed on the Department of Homeland Security's agenda is to "Increase overall preparedness, particularly for catastrophic events" (DHS website, 2005). This research evaluated each detection system and a "do-nothing" option in terms of that goal. The accuracy of each detection method is evaluated by reviewing data collected from past BioWatch data, the SARS preparedness initiatives of 2003, and analysis of the 2001 anthrax attacks in the United States.

Thermal screening data from manufacturers of thermal scanning units is used. Additionally, non-market factors not quantified with economic figures (such as acceptance of technology) is evaluated and incorporated into the analysis. Limitations of the both methodologies are discussed. Areas such as the data management and the pathophysiology of increasing body temperature are covered. Further discussion of these items clarifies a "proof-of-concept." Finally, considerations of a new emerging infectious agent, such as avian influenza, and the morbidity impacts are mentioned.

Chapter 2 - Literature Review

The 2005 National Institute of Health (NIH) budget for biodefense spending was $1.7 billion (Enserink, 2005). Since the anthrax attacks of 2001, annual funding for biodefense research has increased dramatically. “An Open Letter to Elias Zerhouni” published in the 4 March 2005 issue of *Science* challenged whether NIH was distributing these research dollars prudently. Zerhouni is the head of the nation’s medical research institution, the National Institutes of Health (NIH). The letter was signed by 750 U.S. microbiologists – including the president elect of the American Society of Microbiology (ASM) and seven past ASM presidents (Enserink, 2005). Since 2001, there has been a 1500% increase in funding grants for the NIH’s National Institute for Allergy and Infectious Diseases (NIAID) research exploring anthrax, plague, tularemia, glanders, meliodosis, and brucellosis (Altman, 2005). In that same time, grants to study non-biodefense–related agents have decreased by 41% (Altman, 2005). Consider Table 4 comparing the average number of cases of different diseases seen per year in the United States.

Table 4 - Average Number of U.S. Cases per year from 1996 – 2003 by Disease Type (Altman, 2005).

Biological Agent	Average U.S. cases/yr	Biological Agent	Average U.S. cases/yr
Tularemia	122	Tuberculosis	17,403
Anthrax	3*	Salmonellosis	42,457
Plague	5	Shigellosis	23,567
Glanders	0	Syphilis	38,007
Melioidosis	0	Gonorrhea	346,765
Brucellosis	103	Chlamydia	685,508

** includes 22 bioterrorism- related events in 2001.*

Many microbiologists, considering the financial distribution of research dollars and the prevalence of disease between biodefense- and non-biodefense agents, believe this is extremely one-sided. These microbiologists believe the threat is not from the classic category A agents but from emerging infectious diseases. Dr. Robert Armstrong, Senior Research Fellow at the National Defense University's Center for Technology and National Security Policy, reports that between 1973 and 2003, an average of one new disease emerged annually. Some of the more memorable diseases include Legionnaires' disease in 1977, HIV/AIDS in 1981, West Nile Virus in 1999, and SARS in 2003 (Armstrong, 2004). Avian influenza, commonly referred to as bird flu, could be the next on this list.

Many microbiologists believe a combination of four factors makes influenza potentially the most dangerous of all known viruses: it crosses the species barrier readily; it can be very virulent, killing a high proportion of those infected; it is highly contagious;

and it can genetically recombine quickly into more dangerous strains (Financial Times, 2005). It is this ability to recombine quickly that is of concern with the H5N1 avian strain of influenza that has emerged in the Far East.

In its current form, the avian influenza virus does not present a great threat to humans because it is not readily transmissible between humans. When humans do contract the disease though, fatality numbers are high: the World Health Organization's February 2006 report counts 93 deaths among 173 cases for a 53% mortality rate (WHO website, 2006). However, if a human were to contract both H5N1 influenza and seasonal influenza, the viruses could genetically combine into a form with the virulence of H5N1 *and* the human-to-human transmission characteristics of seasonal influenza. In this scenario, morbidity and mortality rates would soar as a contagious and virulent virus is spread world-wide. The word to describe this situation is "pandemic"; it comes from the Greek words for "all" and "people"': "pan" and "demos". Pandemic differs from the word "epidemic." In Greek, "epi" means "upon". Epidemic is an outbreak upon a certain location, community or region. If the location or region is the entire world then the *world-wide* epidemic could be called a pandemic.

The CDC describes pandemic influenza occurring when "a new influenza A virus appears or "emerges" in the human population, causes serious illness in people, and then spreads easily from person to person world-wide (CDC website, 2006). The CDC describes localized seasonal outbreaks, or epidemics, of influenza as seasonal influenza.

Three influenza pandemics have occurred in the last century. The worst of these was the 1918 pandemic which killed at least 20 million people (Gensheimer, 2003). Today a new avian influenza is presenting itself in the Far East: the H5N1 influenza virus. This paper uses the terms "avian influenza" and "H5N1" interchangeably; a separate disease is seasonal influenza and should not be confused the former terms. Experts theorize that the new avian influenza virus has the potential to spread around the globe and become the next pandemic of influenza. The estimated economic impact within the U.S. for the next influenza pandemic has been estimated as high as $166.5B USD (Balicer, 2005). The expected mortality toll in the United States is estimated to be 89,000 to 207,000, with hospitalization numbers expected to be 314,000 to 714,000 and outpatient visits numbering between 18 million and 42 million (Gensheimer, 2003).

Should We Care?

Numbers above show the possible effects of such a virus. They rival or exceed the numbers that would result in the case of a biological warfare attack. As a biological agent, influenza is considered a Category C agent by CDC (see Table 3). Considering the expected effects of pandemic influenza, is the H5N1 virus categorized correctly? To further identify the possible severity of a pandemic avian influenza Gensheimer created Table 5 showing the similarities and differences between a bioterrorist event and a pandemic avian influenza.

Table 5 - Comparison between a Bioterrorist Event and Pandemic Influenza (Gensheimer, 2003)

Planning for pandemic influenza and bioterrorism: similarities and differences[a,b]

Issue	Bioterrorist event	Pandemic influenza
Likelihood	High	High
Warning	None to days	Days to months
Occurrence	Focal or multifocal	Nationwide
Transmission/duration of exposure	Point source; limited; person-to-person	Person-to-person, 6–8 wks
Casualties	Hundreds to thousands	Hundreds of thousands to millions
First responders susceptible?	Yes	Yes
Disaster medical team support/response	Yes	No (too widespread)
Main site for preparedness, response, recovery, and mitigation	State and local areas	State and local areas
Essential preparedness components		
Surveillance	Yes	Yes
Law enforcement intelligence	Yes	No
Investigation	Yes	Yes
Research	Yes	Yes
Liability programs	Yes	Yes
Communication systems	Yes	Yes
Medical triage and treatment plans	Yes	Yes
Vaccine supply issues	Yes (for most likely threats)	Yes
Drug supply issues	Yes	Yes
Training/tabletop exercises	Yes	Yes
Maintenance of essential community services	Yes	Yes
Essential response components		
Rapid deployment teams	Yes	No
Effective communications/media relations strategy	Yes	Yes
Vaccine delivery	Yes (for some)	Yes
Drug delivery	Yes (for most)	Yes
Hospital/public health coordination	Yes	Yes
Global assistance	Possibly	Yes
Medical care	Yes	Yes
Mental health support	Yes	Yes
Mortuary services	Yes	Yes
Supplies and equipment	Yes	Yes
Essential mitigation components		
Enhanced surveillance	Yes	Yes
Enhanced law enforcement intelligence	Yes	No
Vaccine stockpile	Yes (selected agents)	Prototype vaccines only
Drug stockpile	Yes	Yes
Pre-event vaccination	Vaccination of selected groups[c]	Vaccination of groups at medical high risk with pneumococcal vaccine[d]

[a]During a catastrophic infectious disease event, such as an influenza pandemic, there may be critical shortages of vaccines and drugs. Thus, clinics set up to administer vaccines and distribute antimicrobial drugs may require the services of a range of personnel whose fields of expertise are nonclinical. Examples

of additional personnel that may be needed include law enforcement, translators, social workers, psychologists, and legal experts.
[b]Source: Adapted from: National Vaccine Program Office. Pandemic influenza: a planning guide for state and local officials (Draft 2.1). Atlanta: Centers for Disease Control and Prevention; 2000.
[c]At the time of writing, the smallpox vaccination program was just beginning. For other bioterrorist agents for which vaccines are available (e.g., anthrax), limited supplies and concerns about safety profiles have, up to this point, effectively prevented the widespread use of these vaccines.
[d]It may eventually be possible to vaccinate high-priority groups and the general population with a yet-to-be-developed "common epitope" vaccine, which might provide for a broader spectrum of protection against a variety of influenza A subtypes.
Table citation: Gensheimer KF, Meltzer MI, Postema AS, Strikas RA. Influenza pandemic preparedness. Emerg Infect Dis [serial online] 2003 Dec [*date cited*].

Table 5 shows that H5N1 should not be confused with ordinary "seasonal influenza". Seasonal influenza typically occurs during the winter months with some years having higher illness (morbidity) and lethality (mortality) rates than other years. On average, 36,000 people die per year in the United States because of seasonal influenza (CDC website, 2006). While this number is high, the potential loss of life from a pandemic strain of H5N1 is much greater.

To help avoid confusion between avian influenza and seasonal influenza, the scientific and public health communities are promoting the use of the term "H5N1" by the media when discussing the avian influenza disease. This naming convention is being done to distinguish the "H5N1" virus from ordinary seasonal influenza and, hopefully, increase the urgency of research and education initiatives. The CDC website explains that influenza viruses are categorized into one of three types: Type A, B, or C. Birds are the natural hosts to type-A influenza viruses and the H5N1 avian influenza reported in recent media reports is of the type-A variety (CDC website, 2006). The specific nomenclature "H5N1" denotes different proteins on the surface of the virus. The influenza type-A virus has 10 genes which encode for 11 proteins (Zubay, 2005). The

"H" and the "N" stand for different subtypes of two of these proteins. The "H" stands for hemagglutinin and the "N" for neuraminidase. There are 15 different subtypes of hemagglutinin and 9 different subtypes of neuraminidase (Lee, 2004). The subtype of protein on the influenza virus surface determines the name of that particular virus. Hence, the H5N1 virus has the 5th subtype of hemagglutinin and the 1st type of neuraminidase on its surface. Both located on the influenza virus's surface, hemagglutinin and neuraminidase are essential to the viron's life cycle. Hemagglutinin allows the virus to attach to the host cell's plasma membrane and enter into the cytoplasm (Zubay, 2005). Neuraminidase is responsible for releasing progeny viruses from host cells (Zubay, 2005). The two other types of influenza, type-B and type-C, are not named according to subtype and are of lesser concern. Type-B viruses occur only in humans but are not believed to be able to cause pandemic outbreaks (CDC website, 2005). Type-C viruses only cause mild illness in humans and are not able to cause epidemics or pandemics (CDC website, 2005).

Because of the potential toll that avian influenza presents to the economy and human lives (see Table 5), the U.S. should be concerned with H5N1. Early detection of the avian influenza virus will be one key to minimizing the impact of a pandemic.

Syndromic Surveillance and BioSense

Currently, emerging infectious diseases are often discovered when patients present at health-care facilities, such as clinics, hospitals, or physician offices. In time, when large numbers of patients present similar symptoms, an astute medical professional

will recognize the similarities and investigate the causative agent. This is often how an emerging infectious disease is discovered. Using information technology to track similar symptoms presenting at multiple health-care facilities and highlighting this statistical spike is the idea behind syndromic surveillance. Tying the different health-care facilities' data into one system and effectively monitoring data anomalies is a difficult task. The CDC's BioSense program exists to address this need.

BioSense is under the Public Health Information Network program (see Table 1). The Public Health Information Network is a national initiative involving multiple organizations sharing information to identify outbreaks of disease. Colleen Bradley, a public health analyst for the BioSense project, describes it as a CDC initiative, implemented in April 2004, to support enhanced early detection, quantification, and localization of possible biologic terrorism attacks and other events of public health concern on a national level (Bradley, 2005). The focus is on earlier detection for the local and state public health agencies. Earlier detection facilitates a more timely response and thereby mitigates the negative effects of a biological event. Algorithms identify statistical anomalies in Department of Defense and Department of Veterans Affairs ambulatory clinical diagnoses, in procedural data, and in Laboratory Corporation of America laboratory-test ordering data (Bradley, 2005). Stratifying these data by location and time helps determine trends and clusters of disease that are emerging.

BioWatch

The U.S. government currently uses the system "BioWatch" as the basis for the country's biosurveillance detection methodology. DHS is responsible for deploying this system as part of the Biological Warning and Incident Characterization System.

BioWatch consists of an area air sampler that collects large volumes of air. Samples must be manually collected and transported to a laboratory. Once in the laboratory, the air samples are analyzed for the presence or absence of harmful biological agents. Sample analysis is performed on a regular basis. The periodicity of sample collection and analysis is not made available to the public, but it can be assumed to be resource-intensive. While the entire cost of the BioWatch program is unknown, the capital costs for installation in a single city are estimated at $1 million and the yearly budget for operation at $1 million per city (Shea, 2003). Recent press reports have quoted higher costs; the total cost of BioWatch deployed to 31 cities has been cited as $60M (Charles, 2003). The 2005 initiative to increase the number of cities participating in BioWatch is expected to increase the program cost to $118M (Charles, 2003).

This methodology only looks for a finite number of biological agents and will not identify an emerging strain that has not been previously identified. Further limitations are discussed below.

BioWatch Limitations

When collecting air particulates, the size distribution is governed by the filter used to collect that sample. This results in a wide variety of particle sizes collected. Some of these particles are of the size which the human body is susceptible to, but others are too small or too large to be of concern to the human body. The natural defenses of the body effectively remove them and thereby render them harmless.

BioWatch collects air samples wherever the sampling devices are positioned. Theoretically, detectors would be placed in high-threat locations based on intelligence and locations based on prevailing weather conditions to optimize detector interaction with biological agent releases. In reality, weather conditions change, resulting in suboptimal positioning of detectors. Additionally, urban environments present unique environments with unusual air currents. Depending upon the architecture of the city, eddy currents and dead spots may exist between buildings, further compromising the utility of fixed detector locations.

Samples collected are then analyzed for the presence of a biological agent of concern. The Category A agents that the CDC has published as "the most easily disseminated or transmitted from person to person, cause high mortality rates, and have the potential to disrupt both public health and social life" are most likely screened for (CDC website, 2005). Undiscovered emerging infectious diseases are not analyzed.

Continuously sampling the environment for harmful biological agents has not previously been undertaken. The EPA has deployed air samplers across the country and we commonly see the results of these activities in the weather section of the daily newspaper and on local news broadcasts. Pollen count, smog indices, UV levels, and mold counts are examples of items that are monitored daily but continuous sampling for harmful biological agents has not been previously performed. First, the scientific community has not identified the vast majority of organisms that exist on the planet today. Soil ecologists commonly state that they have perhaps identified one percent of the organisms living in topsoil; of the remaining 99 percent, most of the organisms are bacteria (Zelicoff, 2005). A similar percentage of unidentified organisms exist in the air. It is unknown what continuous sampling results would yield – what are the agents that public health officials need to concern themselves with? A second and larger problem has occurred at least three times since inception of the BioWatch program.

In the winter of 2002, analysis of BioWatch samples identified at least one anthrax spore using polymerase chain reaction, a technique so specific that one spore of anthrax could result in a positive identification. Should one anthrax spore be of concern to the population of New York? Past studies show that workers not immunized in wool mills could inhale several hundred spores daily without developing disease (Dahlgren, 1960). The subsequent actions were problematic. A response procedure was not developed to deal with such an incident. After analysis, no other BioWatch samplers tested positive for anthrax. No spikes in syndromic surveillance were noted. With no additional pieces of information, what was the appropriate action? The anthrax

bacterium is endemic to many parts of the United States, especially where cattle farming operations occur. A hardy spore-forming bacteria, *Bacillus anthracis* can remain viable in the soil for decades. The natural background concentration of anthrax spores was unknown and so was the appropriate response. In the end, no public notification took place and the source of the anthrax was not determined. However, the positive anthrax identification did cost millions of dollars and many hours of the New York Department of Health's resources.

In October 2003, BioWatch samplers again collected an agent of concern; this time the bacterium that causes tularemia. The city was Houston, TX. Indicative of a malicious release, three BioWatch units aligned in the path of predominant weather all tested positive. Tularemia is endemic to the southwestern parts of the United States and has a reservoir of rodents and rabbits. It is sometimes referred to as “rabbit fever” and is caused the bacterium *Francisella tularensis*. The background concentration of tularemia in Houston was unknown; distinguishing between a natural event versus a malicious release was not possible. Similar to New York, there was no agreed upon response plan. The Houston Department of Health increased air sampling and examined local rodent and rabbits, considering them as a possible source. In the end, the source of the three positive samples for tularemia remained unknown, but not before valuable time and resources were spent investigating the incident.

Francisella tularensis was the agent of concern again in September 2005. More than 6 BioWatch sensors picked up tularemia bacteria in the Mall area of Washington,

D.C on 25 September 2005, but the CDC was not notified for at least 72 hours after detection (Levine, 2005). Asked why such a delay occurred, the director for the CDC's Coordinating Office for Terrorism Preparedness and Emergency Response, Richard Besser, stated because subsequent tests were not conclusively positive (Levine, 2005).

All three of these examples are indicative of a limitation associated with the BioWatch response time. Table 2 describes a maximum response time from release until detection of 36 hours. These three examples show response times longer than this. The point isn't to dispute the use of subsequent testing to assure the validity of a detection of harmful biological agents. Confirmational sampling is required to avoid unnecessary use of resources and undue alarm in the public. The limitation is in reference to the benefit provided to society. This paper quantifies benefit by the reduction in mortality due to the surveillance in place. The reduction in mortality is heavily dependent upon the time to initiate response actions. If actual response times are hindered due to confirmational testing requirements, estimates of mortality numbers will not be accurate nor will the societal benefit.

Infrared Thermal Scanning

Infrared radiation thermometry is now commonly used as a standard methodology to measure the temperature of the human body. As a non-invasive approach, the infrared ear thermometer is both quicker and easier to use than oral thermometers. This technology can also be applied in a mass screening mode measuring individual body temperatures quickly. This use was employed to combat the outbreak of SARS in 2003.

SARS caused 813 deaths in the 8,437 cases that were reported world-wide during 6 months of 2003 (Wu, 2004). The disease, with an average mortality of 10%, is communicable and was reported in 29 countries around the world (Wu, 2004). The cardinal symptom of SARS is fever, but conventional means of measuring human body temperature with oral, and even ear, thermometers were slow and cumbersome. Attempting to control the spread of this epidemic, Singapore employed infrared technology to screen mass numbers of people in 2003. The Singapore Ministry of Health (MOH) consulted with their Defense Science and Technology Agency (DSTA) who used their Sensor Systems Division (SSD) to find a solution (How Tan, 2004). Within one week a prototype was built to measure large numbers of people quickly. The Infrared Fever Screening System (IFSS) was released shortly thereafter.

Infrared Fever Screening System with "A Hot Idea"

The IFSS was implemented to identify individuals with fever with follow-up investigation to determine whether febrile persons had SARS. Incorporated into "A Hot Idea," IFSS would be looking for *an elevation in temperature*. The distinction between a fever and an elevation in temperature is an important one in understanding the basis for "A Hot Idea."

A fever is commonly defined as measurable sign of infection; often a body temperature of 38°C or greater is cited as the threshold for fever. An elevation in temperature is one of the initial mechanisms the body responds with after becoming

inoculated with a foreign agent. The rise in temperature could be to 38°C or higher, but it doesn't have to be. Any increase in temperature from an individual's baseline temperature initiated by the immune system constitutes an elevation in temperature. An elevation in temperature is before the onset of symptoms and signs of a fever because the individual does not recognize it as a fever nor does the medical community determine a fever through measurement. Further discussion follows in the report regarding the pathophysiology of fever and the body's mechanisms at work to elevate temperatures from the baseline temperature.

Infrared Fever Screening System[2]

IFSS uses a two-tier detection concept to screen a large group of people for fever: the first is the detection of feverish individuals with the infrared technology; the second is confirmation testing with conventional means, i.e. oral or ear thermometers (How Tan, 2004). The IFSS measures exposed areas around the face of screened subjects where the blood vessels are relatively close to the surface of the skin. These areas were determined to be areas around the temples, neck and a small patch of skin between the eyes and nose (How Tan, 2004). Additional studies have focused on a specific location on the forehead and the inner corner region of the eyes because these areas are not normally covered by the subjects and have a temperature close to the body's core temperature (Ng, 2005). The IFSS compares the infrared heat given off by a subject to the infrared heat given off by a separate thermal reference source (TRS). Calibrated and set to a pre-determined reference

[2] Discussion of IFSS uses the correct term "fever" due to IFSS use during the 2003 SARS outbreak. When incorporated into "A Hot Idea," IFSS would be configured to look at the earliest *elevation in temperature.*

temperature, comparisons between the TRS and the subject are made. Software converts the differences between the TRS temperature and the subject temperature and assigns different colors to represent different temperatures. Red often signifies elevated temperatures above some threshold temperature (Wang, 2004). The degree of increased temperature is indicated by the density of the red region and the amount of red surface area on the subject. Figure 1 below shows the typical output by this type of infrared scanner.

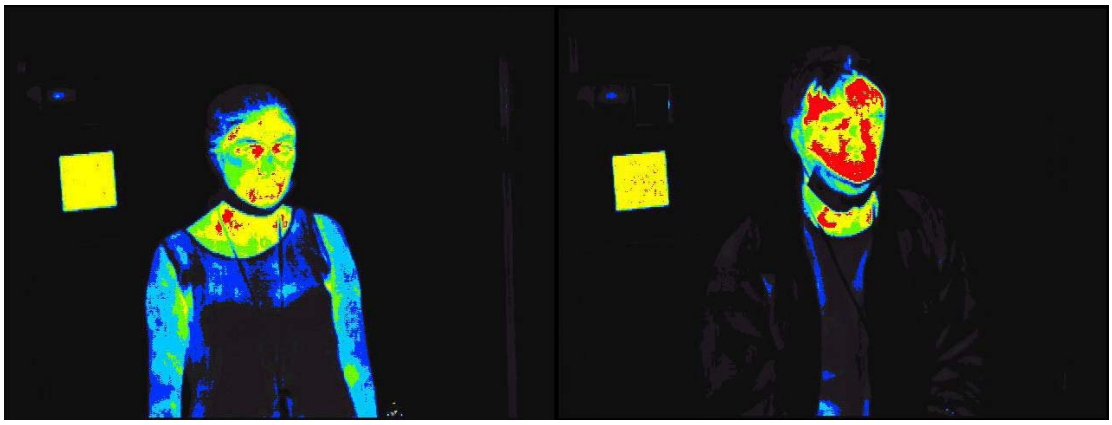


Figure 1 - Typical Output by Infrared Fever Screening System Type Thermal Scanner. Left photo shows normal temperature; right photo show elevated temperature. Notice the Thermal Reference Source in the background of both photos. (Wang, 2004)

The relationship between one's core temperature and skin temperature varies with the subject and the environmental conditions. Understanding and correcting for these variables is paramount to assuring the accuracy and minimizing false positive and false negative screening results. Human beings control their temperatures internally, although changes in temperature may occur through the physical processes of convection, conduction, radiation, and evaporation. Figure 2 shows the proportional amount of heat loss through the different mechanisms.

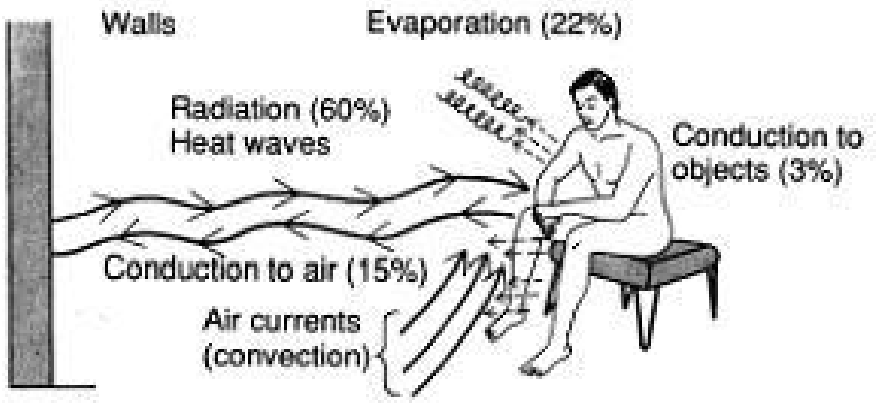


Figure 2 - Human Heat Loss through Various Mechanisms (How Tan, 2004)

Maintaining the body's desired temperature is done through the endocrine system and a specific part of the brain called the hypothalamus. The hypothalamus establishes a target temperature for the body to maintain. For a healthy individual, a target temperature of 37°C is considered average; however each person has his or her own baseline temperature, usually between 36.4°C and 37.7°C (Prewitt, 2005). Excluding illness or exercise-induced hyperthermia, a person's body temperature varies less than 1°C during their lifetime (Prewitt, 2005). This temperature is the homeostasis temperature. Homeostasis is a state of internal consistency in the body, or the normal range expected in a healthy individual. Other average ranges for the body are a blood pH in the range of 7.35 – 7.45 and a blood glucose level of 75 – 110 mg / 100mL. The body acts through different mechanisms that are negative feedback loops to maintain the target range. A negative feedback loop involves an effector (generally a muscle or a gland releasing a hormone or an enzyme) whose purpose is to return the body to homeostasis. As the body returns to homeostasis the effector is no longer triggered by the body and the feedback loop is completed. With body temperature, variations from the average

temperature of ~37°C are counteracted by different actions of the hypothalamus. If the temperature is above the normal range for that body, the hypothalamus triggers the dilation of blood vessels and the activation of sweat glands to release body heat. Conversely, if the body temperature is too low, the body constricts blood flow to the extremities and, if necessary, induces shivering to raise the temperature back to the normal range. A feedback loop shown in Figure 3 describes this process.

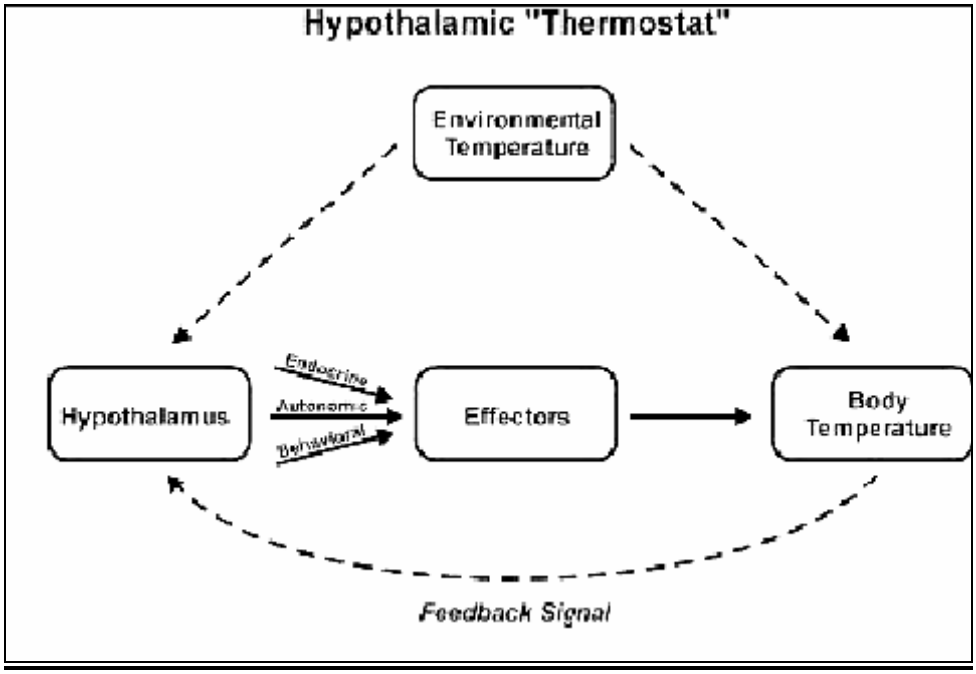


Figure 3 - Hypothalamic Regulation of Human Body Temperature (How Tan, 2004)

Limitations of the IFSS

The thermoreceptors in the skin are more sensitive to rapid changes in temperature than to gradual changes and therefore the subjects should be acclimatized in a stable environment before being screened. For example, subjects should not be screened immediately after entering a warm room from a cold environment. (How Tan,

2004). This may present challenges to "A Hot Idea" when commissioned workforce of policemen, firemen, and mail carriers return from cold outdoor environments after the conclusion of work shifts.

How Tan notes that the IFSS requires subjects to be at or close to resting metabolic rate (How Tan, 2004). Problematically, policemen, firemen, mail carriers and others may be ending their work shifts with elevated metabolic rates due to the duties performed that day.

The body increases temperature when the hypothalamus detects pyrogens and raises the body's baseline core temperature. Pyrogens are proteins that result from the activity by the body's immune system. They can be exogenous (derived from invading microorganisms) or endogenous (derived by the body's white blood cells). The hypothalamus acts as the body's thermostat and establishes a baseline temperature to maintain. To initially elevate temperatures, the body constricts the flow of blood to the surface thereby minimizing heat loss. The skin temperatures during this phase are not elevated and would not be detected by the IFSS. This scenario increases the chance for a false negative. The time course of a typical fever is shown in Figure 4.

The following discussion of IFSS used the correct term "fever" due to its use during the 2003 SARS outbreak. IFSS would be incorporated into "A Hot Idea" but would be configured to look at the earliest *elevation in temperature*.

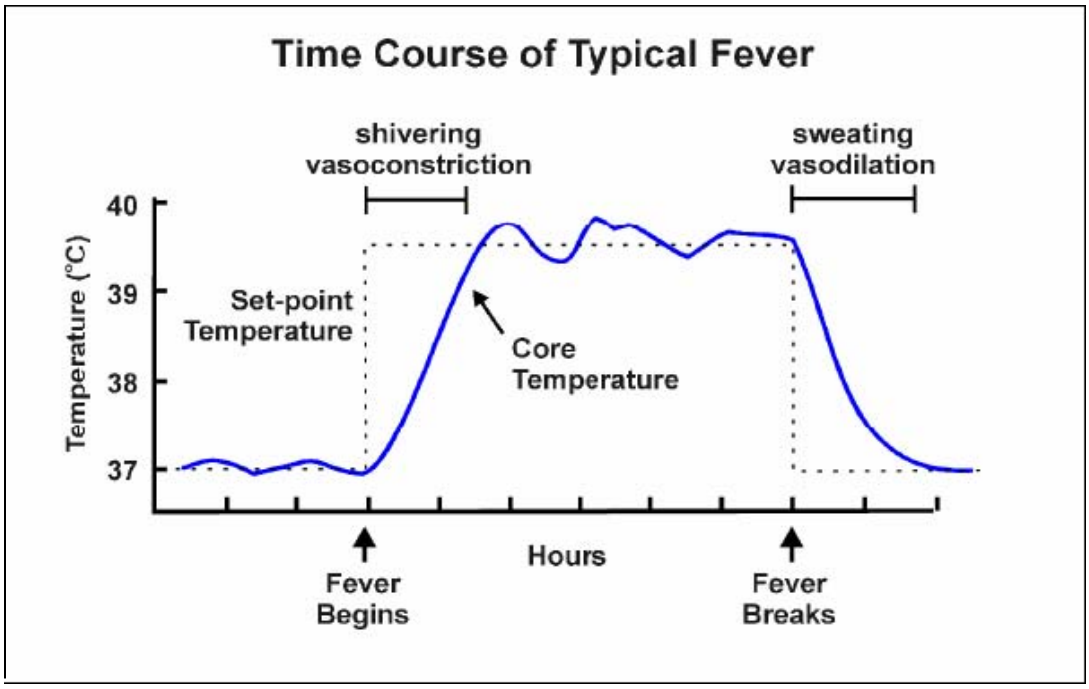


Figure 4 - Time Course of Typical Fever

Types and Limitations of Infrared Thermal Scanners

The IFSS is one type of thermal scanner (TS). Wang evaluated more than 30 thermal imaging systems. Considering the different characteristics in terms of system set-up and working principle, Wang categorizes TS into four types.

TS Type One.

The IFSS described previously is a Type One TS. This type of thermal imaging system is comprised of a thermal imager and an thermal reference source (TRS). The principle of measurement is the temperature difference between the subject and the TRS, which is set at a pre-determined threshold temperature. No quantitative temperature is shown with a type one TS; the delta between the external TRS and the body is the value of interest. The threshold value of the TRS depends on empirical correlation between the

skin temperature and the body core temperature. Clinical trials collect the empirical data: a number of people with various body temperatures undergo thermal scans, and core temperature measurements using oral or infrared ear thermometers. The skin thermal profiles referenced to the TRS setting are then studied. The aim of the tests is to find the correlation between skin temperature and body core temperature and determine the temperature of the TRS (Wang, 2004).

One limitation of the Type One TS is the variance due to environmental conditions. The temperature stability of the subject and the TRS is of concern when the system is not set up in an area with constant ambient conditions. The location of the Type One TS must be in an area free from external drafts or disturbances in the air (Wang, 2004).

TS Type Two.

A second type of TS quantitatively measures the temperature of a screened individual; an external TRS is not used in this configuration. The thermal imager uses a quantitative camera and assigns a temperature to the subject. A threshold isothermal temperature is determined and an alarm signals when a person's facial skin temperature is above this temperature. Wang describes one manufacturer's recommendation to use multiple threshold settings. In that case, the thermal imager is set to 16 different isothermal colors in increments of 0.5°C, thereby categorizing people into one of 16 categories based on their temperature ranges (Wang, 2004). Figure 5 below shows the typical output by a Type Two TS.

Figure 5 - Typical Output by Type Two Thermal Scanner. Left photo shows slight fever of 37.7 degrees Centigrade; right photo show elevated temperature of 38.2 degrees Centigrade. Reference temperature is 36.9 degrees Centigrade in both photos. (Wang, 2004)

Significant drift of the detectors is a concern with the Type Two TS. Self-correction calibration mechanisms have been developed but the time required for these corrections may hinder throughput of the TS process. Self-correction may also reduce the working life of the shutter mechanism (Wang, 2004). Figure 6 below shows an example of drift problems that are associated with Type Two TS.

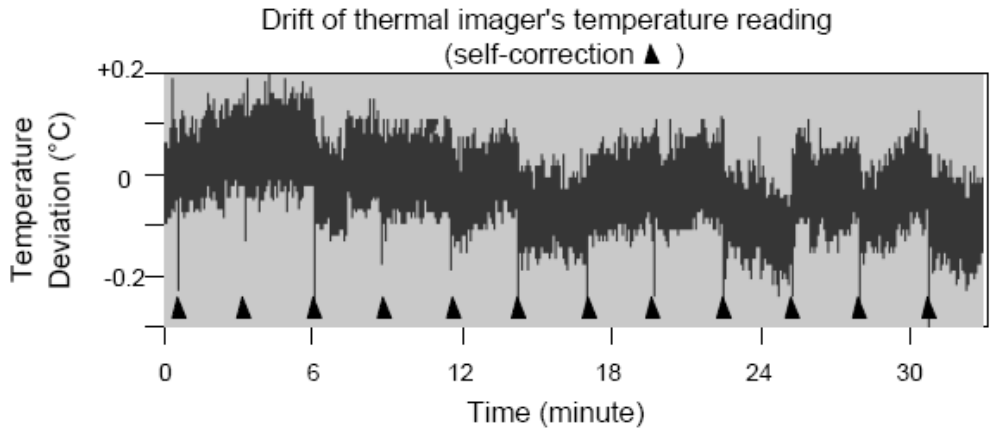


Figure 6 - Typical Drift Seen with Type Two Thermal Scanner (Wang, 2004).

TS Type Three.

The third type of TS incorporates ideas from both the Type One and Two TS; an external TRS is used and temperature quantification is provided. Type Three TS are configured with a TRS that has two set-points, several degrees apart (Wang, 2004). The TRS operates under the same principle as the Type One TS. Typical output by a Type Three TS is in Figure 7.

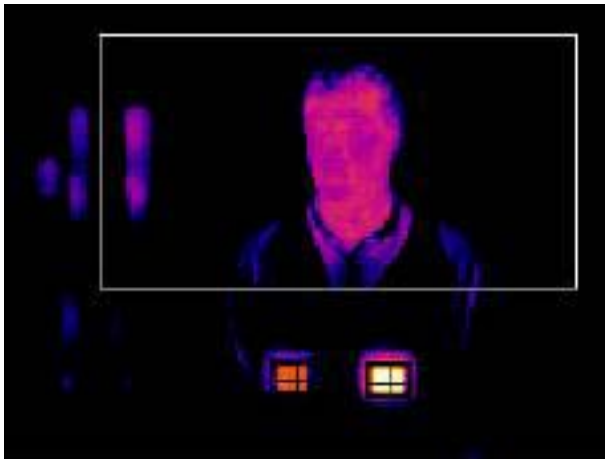


Figure 7 - Typical Output by Type Three Thermal Scanner. Note the two thermal reference sources shown at the bottom of the figure (Wang, 2004).

Wang states that the Type Three TS has some problems with the initial calibration. Operators pick a set of pixels of the TRS on their thermal cameras and assign a temperature to them. TRS are not usually uniform in temperature and the selection of the particular pixels makes a great difference in overall system accuracy. Additionally, the TRS are assigned temperature values by the manufacturer. Unique environmental conditions may influence these temperatures away from the manufacture's specifications and introduce measurement error. (Wang, 2004).

TS Type Four.

The fourth type of TS incorporates a temporal thermometer to give a measurement of core temperature. The system set-up is similar to the Type One TS, except the temporal thermometer measures temperature in a major artery (temporal artery on the side of the head) and thereby more accurately reflects the body's core temperature. The system uses the same TRS as the Type One TS. The TRS is set to reflect the threshold temperature of a fever. Measuring both subject and TRS temperatures at the same time, software packages can determine the difference between the temperatures and notify operating personnel of a fever. The Type Four TS also has software associated with it allowing differentiation between human faces and other warm objects. In Figure 8 notice the system's focus on the subject's forehead instead of the subject's hot cup. Only one of the thirty thermal scanners Wang tested was a Type Four TS.

Figure 8 - Typical Output by Type Four Thermal Scanner. Note the core temperature reported and pixel identification focusing on the subject's forehead (Wang, 2004).

Parameters of Thermal Scanners

Wang discusses several parameters that should be considered to ensure accuracy and statistically significant thermal scanner results. The environment set-up, expected volume of personnel to be screened, training of operating personnel and other factors should be considered with the parameters discussed next to decide upon the most optimum TS unit.

Thermal Drift.

Minimizing thermal drift should be a goal when considering type two scanners. The drift is defined as the change of temperature during the time interval between self-corrections (Wang, 2004). The variance from the true temperature is another way to explain the drift.

Minimum Detectable Temperature Difference.

The Minimum Detectable Temperature Difference (MDTD) is the smallest temperature change that a TS is able to detect by a color change or, the temperature difference corresponding to a 5% to 95% target area color change (Wang, 2004). The smaller the MDTD, the better the TS. Wang considered MDTD values of 0.3°C to be good. Some systems studied by Wang had MDTD of greater than 0.6°C. To avoid the incidence of a false negative (i.e. person with an elevated temperature passing through the system undetected), the threshold has to be adjusted (lowered) by the MDTD. For example, a system with a MDTD of 0.5°C and threshold temperature of 37.5°C would

have to lower the threshold temperature by the MDTD (0.5°C) to eliminate a false negative due to MDTD error.

Non-uniformity.

The parameter of non-uniformity concerns the temperature gradient across the plane of surveillance. Ideally, the temperature would be isothermic and not vary across the target plane. A small non-uniformity coefficient would offer more deployment options. Manufacturers report non-uniformity measurements in a workable target plane as opposed to the system's overall target plane. The workable target plane is defined as 2/3 of the size of the target plane (Wang, 2004). Non-uniformity measurements in the target plane would be greater than those in the workable target plane. Measurements are taken from the center, four corners and in-between the four corners of the workable target plane as indicated in Figure 11. Measured non-uniformity measurements ranged from 0.2°C to 2°C. A TS with a non-uniformity measurement of 2°C means the same person could report temperatures of 38°C and 36°C dependent on whether the subject was located in the center or corner of the workable target plane.

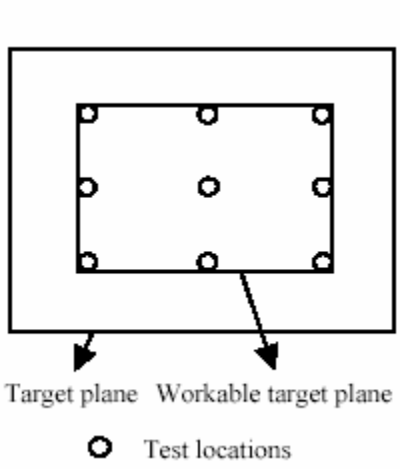


Figure 9 – Thermal Scanner Test Locations for Measurement of Non-uniformity Parameter (Wang, 2004).

Distance Effect.

This parameter involves the difference in temperature readings from a arbitrary distance. A smaller distance effect results in more configurations and more versatile environments the TS system can be set up in. Units with large distance effects can still be considered for use if the units are set up in a structured environment that reduces the distance to the TS such that a more reasonable and competitive distance effect can be achieved.

Calibration/Stability of threshold temperature.

The threshold temperature is a reference point that the TS uses to differentiate an elevated temperature from a average temperature (Wang, 2004). The calibration of the reference temperature is traceable to a uniform standard, specifically the International Temperature Scale 1990 (ITS-90). Ensuring a consistent reference point throughout the entire operation time is paramount to accurate screenings. To determine the stability of

this reference temperature other parameters must be considered. The non-uniformity of the TS must be accounted for; manufacturers often measure variance from the threshold temperature at the center of the target plane. The location of the TRS in the target plane must also be considered for TS types Three and Four. Wang reports that the established brands tended to demonstrate smaller errors. Type One TS are not affected by this method of threshold setting because Type One TS thresholds are derived from clinical trials.

Spatial resolution.

The spatial resolution depends upon the size of the detector used. Wang does not go into great discussion with this parameter except to say that an adequate number of pixels must be captured and analyzed by the detector. If a cold spot on the subject is analyzed, the mean temperature of the individual could be skewed, thereby presenting the possibility of a false negative.

All the parameters discussed have importance in facilitating a quick, efficient, and accurate thermal scanning process. Of all the parameters discussed, Wang believes MDTD and non-uniformity to be critical parameters (Wang, 2004). Wang analyzed more than 30 TS and found no outright configuration that was superior to the rest. When selecting a TS unit for the screening of a commissioned workforce as described in "A Hot Idea", all these parameters must be considered. If the limitations of the particular TS are known ahead of time, the set-up configuration can be manipulated to minimize some of these shortcomings. For example, ensuring the TRS is not in an area of changing

environmental conditions, minimizing the distance between thermal camera and subject, or using the central portion of the working target plane would minimize limitations of different TS units with their respective parameters.

Economic comparison

Society has expressed an interest in biosurveillance. The post-9/11 world has introduced both a real and perceived threat to the U.S. public. At the same time, nature continues to create new infectious agents for which the public must be prepared. The belief that the discovery of antibiotics would lead to a disease-free society has been proven wrong. Kathleen Gensheimer, Maine's State Epidemiologist and Direct of Medical Epidemiology, and others in the scientific community, have expressed some of the possible effects that one emerging infectious agent, H5N1 avian influenza, could have on the U.S. society. Better detection and identification methods for biological agents have been identified as a need but there are several ways to go about conducting this surveillance.

Two such detection methodologies will be compared against a "do-nothing" approach in this paper. The technology with greater economic value will be considered the superior methodology. The economic analysis is discussed below. After determining the superior methodology, there is an optimal amount of spending that can be invested before there is loss on investment. To arrive at objective conclusions to these questions, economic tools are used. Three types of analyses could be used to evaluate different approaches: Benefit-Cost, Cost-Effectiveness, and Cost-Utility studies.

Different Economic Approaches

The Benefit-Cost Analysis (BCA) is described as the "gold standard" by many applied economists (Meltzer, 2001). All costs and benefits are measured with economic terms and are adjusted to a net present value for future years. Simply stated, if the net present value of the benefits outweighs the net present value of the costs, that strategy is said to have an overall positive net present value. This analysis approach is particularly useful when comparing two different options; the one with the larger net present value is considered the superior option.

Both the Cost-Effectiveness Analysis (CEA) and the Cost-Utility Analysis (CUA) analyses consider the benefits in terms other than monetary units. The CEA might deliver an output in particular units of a health outcome (e.g. lives saved) (Meltzer, 2001). The CUA incorporates a value for the quality of life ranging between 0 and 1. For example, an individual that loses a leg is considered to have a lower quality of life than an individual that has partial use of a leg, which is still less than a person with two healthy legs. Neither the CEA nor the CUA deliver an output in strict economic terms. Additionally, the CUA is better suited for chronic conditions. To arrive at an objective evaluation with economic terms on a societal basis for acute illnesses, the Benefit-Cost analysis was chosen for this study.

BioWatch costs an estimated $1M to deploy to a city and an additional $1 million dollars annually for operations and maintenance (Emory, 2005). Alternatively, the costs

Canada incurred for operating thermal scanning units in 2003 are reported at $66,667 per unit annually for rental costs (The Vancouver Sun, 2003). Personnel, and operation and maintenance, costs were reported at $700,000 per unit annually (The Vancouver Sun, 2003). In the simplest form, if both of the detection methodologies had the same accuracy and early-detection timetables for all biological agents, the methodology with the lower capital and amortized costs would provide a greater net benefit to society than the methodology with the higher capital and amortized costs. The methodology with the greater net benefit to society would then have to be compared with a "do-nothing" approach. If the surveillance costs exceed the "costs avoided", the "do-nothing" approach would be warranted. Alternatively, if the averted costs exceed the surveillance costs, biosurveillance would be warranted. Additionally, since BioWatch is currently operating in 31 cities across the county, sunk costs must be considered. Comparing the two methodologies will depend on whether BioWatch has been previously deployed to the geographic area of interest. Anthrax is one agent that both methodologies would likely have comparable early-detection times and accuracy.

If, however, an emerging-infectious disease not screened for under standard sampling and analysis BioWatch protocols is considered, a more rigorous analysis is required. Market-based economic terms can predict objective overall benefits. Simply stated, market-based value is a price range for which the market will buy or sell a service or good. For example, there is a market-based value for a professor: universities have demonstrated a willingness to pay some amount of money for the services of a professor with certain qualifications and, at the same time, professors have agreed to provide those

services for this same range of salary. Similarly, there are market based values for all goods, services, and individuals' time including: visits to medical facilities, prescription and non-prescription drugs and days missed from work. Additionally, there are market based values for an individual's life considering a range of values an individual is expected to experience in their lifetime.

The perspective of the costs associated with the analysis must also be considered. From the perspective of an individual, the benefit of having early notification of an infectious outbreak is the costs saved due to a decreased risk of contracting the disease. The benefit realized by the individual can be estimated as the diminished chance of contracting illness which would have resulted in costs associated with lost time from work, travel associated with visits to a physician, and co-payments. The benefit realized by the health insurance provider would include the cost avoidance from a visit to the physician, but would not consider savings associated with the patient's travel time saved or their social engagements kept. Conversely, the health insurance company could realize a negative-benefit due to early notification of the presence of H5N1: "worried-well" patients may present en masse to health care facilities requiring reimbursement from the insurance company. Different again, pharmaceutical companies may realize a profit from early notification due to a large demand for pre-treatment drugs. Or would the profit losses associated with a smaller illness rate result in less overall pharmaceutical products being prescribed? Meltzer discusses this issue and concludes that policy makers often contend with the perspective issue. In the end, they often focus on the benefit from a total society perspective. "Adding up all the costs and benefits

irrespective of who pays and who benefits … societal perspective is the most comprehensive one; all others are subsets of the societal perspective (Meltzer, 2001)."

Chapter 3 – Methodology

Economic Impact Considerations

The economic impact attributed to the release of a biological agent should be quantified to develop sound prevention measures. The impact of a bioterrorist attack depends on many factors. Characteristics of the agent, the delivery method, the population exposed and the response reaction by both emergency responders and society as a whole all influence the magnitude of an event involving the release of a biological agent.

The number of people exposed and the virulence of the agent are two important criteria to consider. Virulence is attributed to the specific agent; *Bacillus anthracis* possesses a different virulence than *Francisella tularensis*. The virulence is also affected by the atmospheric conditions and size distribution of the agent. For example, to efficiently enter the lungs, anthrax spores must be between 1 μm and 5 μm in diameter (Reshetin, 2003). If the spores are smaller than this diameter, they will be inhaled and then immediately exhaled without being deposited in the alveolar region of the lungs. Spores greater than 5 μm will be trapped in the nose hairs and mucous linings of the nose and throat; they will be expelled without lodging in the lungs and causing disease. Additionally, the spore size distribution may be between 1 μm and 5 μm but the spores may agglomerate together and settle out of the atmosphere faster than a "weaponized" version of the agent. The *Journal of the American Medical Association* described the Hart Senate anthrax powder of 2001 as "weapons grade" and "exceptional" in that it had

a high spore concentration, uniform particle size, low electrostatic charge, and had been treated to reduce clumping (Matsumoto, 2003).

The method used to distribute the agent will also influence the effects of a biological release. Distribution characteristics concern both the mechanism used to deliver the agent (e.g. subway release, aerial sprayer, introduction into a ventilation system, etc.) and the environmental conditions (e.g. wind speed, temperature inversion, disinfecting ultraviolet light intensity, etc.).

Characteristics of the population also influence the magnitude of the event. The population's immunity to the disease is one important consideration. The time between exposure and receiving medical attention, to include pre-exposure prophylaxis, is also important. Kaufmann states this is the single most important factor influencing the economic impact of biological agent release (Kaufmann, 1997). The amount of "worried-well" in the population using limited medical resources (including limited facility space, medical manpower, equipment, and pharmaceuticals) will influence the magnitude of the event.

Wein Model

All of the characteristics discussed above are dwarfed when considering variations in the size of the release. Lawrence Wein from Stanford's Graduate School of Business, David Craft from Massachusetts Institute of Technology's Operations Research Center, and Edward Kaplan from Yale's Department of Epidemiology and Public Health

produced a model to predict the outcome of a 1 kg release of anthrax concentrated at 1 trillion spores per gram in a city of 10 million inhabitants. For comparison, New York City has a population of 8.1 million inhabitants and a metropolitan population of 18.6 million (City Population website, 2005). Other cities with metropolitan populations close to 10 million are Los Angeles and Chicago with 12.8 and 9.3 million inhabitants, respectively (City Population website, 2005). The study uses a system of models to address different facets of an attack. An atmospheric dispersion model, an age dependent dose-response model, a disease progression model and a model simulating the volume expected at medical facilities specifically for antibiotic distribution and hospital care were all used to generate an output quantifying the impact of an anthrax release. A graphical depiction of Wein's system is presented in Figure 10 below.

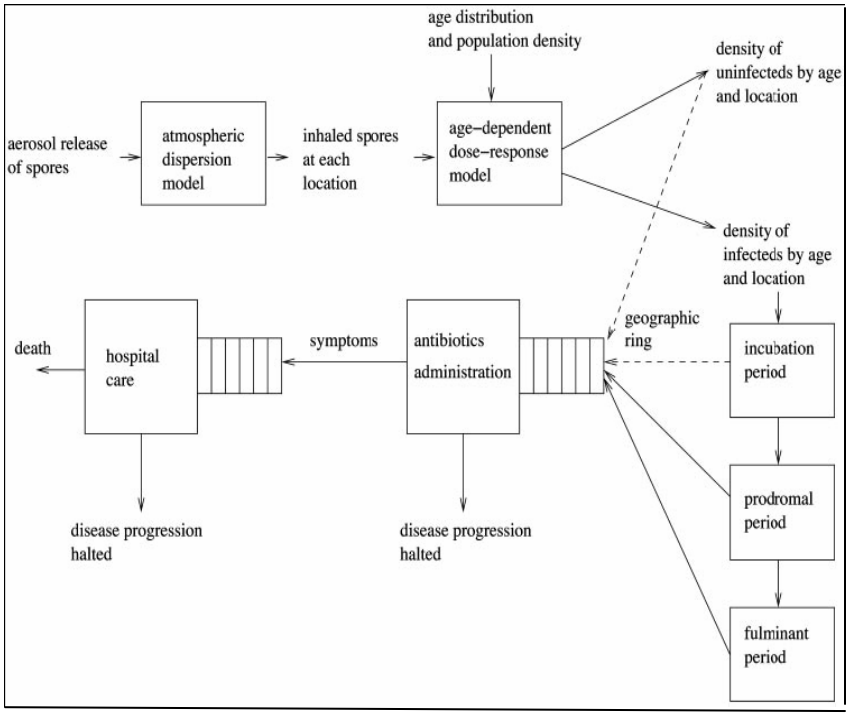


Figure 10 - Graphical Depiction of the System of Models Used to Quantify the Impact of an Anthrax Release (Wein, 2003).

The atmospheric dispersion model used by Wein is a Gaussian plume model identical to the one used in the paper titled *The Sverdlovsk Anthrax Outbreak of 1979* (Meselson, 1994).

Sverdlovsk Anthrax Incident

The anthrax incident in the former Union of Soviet Socialist Republics town of Sverdlovsk is the most deadly anthrax epidemic known in modern times; at least 68 people died (Wampler, 2001). The incident and size of release remain controversial today. The Soviet Union claimed a natural outbreak of anthrax and subsequent ingestion of anthrax contaminated meat as the responsible cause for the cluster of deaths in 1979. The United States, on the other hand, believed the Soviet Union was in violation of the 1972 biological weapons convention. The Central Intelligence Agency (CIA) asked Harvard biologist Matthew Meselson to examine the evidence and determine release characteristics (Wampler, 2001). In the end, Meselson reported that the outbreak was a result of a daytime aerosol release from a military facility on Monday 2 April 1979 (Meselson, 1994). The weight of the spores released was reported "as little as a few milligrams or as much as nearly a gram" (Meselson, 1994). This is the same base model that Wein uses to predict outcomes of a 1kg anthrax release in a large city. It should be noted that Meselson's model output was contested by U.S. biological weapons experts; they believed his estimate to be low. Thirty-year biological weapons researcher, Dr. William C. Patrick, an expert on anthrax dispersal, stated he and other experts "hooted" when Meselson presented his low estimate (Miller, 2002). Dr. Ken Alibek, the former deputy director of the Soviet biological warfare operation Biopreparat, now working for

U.S. intelligence sources, backed the U.S. position stating that the Sverdlovsk military facility was one of the Soviet Unions busiest production plants for anthrax production, "working around the clock, in three shifts" (Miller, 2002). Alibek explained the enormity of the Soviet program in testimony to the 106th Congress: "Hundreds of tons of anthrax weapon formulation were stockpiled, along with dozens of tons of smallpox and plague. The total production capacity of all of the facilities involved was many hundreds of tons of various agents annually" (Alibek, 2000).

The aim of the Wein paper was to determine the most effective manner to distribute antibiotics and hospital care to those showing symptoms of anthrax disease and those who are asymptomatic (including both the "worried-well" and those who are yet to show symptoms). Wein used a threshold parameter *p* that determines the fraction of all inhabitants that receive antibiotics in a time-varying geographical ring that grows as the fraction of inhabitants displaying symptoms exceeds *p* (Webb, 2003). Ideally, all personnel will receive antibiotic prophylaxis, regardless if they are symptomatic or not. Even in this idealized scenario, deaths are expected to be 100,000 for a city of 10 million when response is undertaken at 48 hours after release of anthrax (Wein, 2003). Conversely, if antibiotic treatment is withheld until personnel are symptomatic, deaths are expected to be 7 fold higher, or around 700,000 (Wein, 2003).

Value of Statistical Life

Using these mortality numbers, the value of lives lost can be calculated. Numerous studies have been conducted determining an accurate value to put on human

life, specifically for purposes of evaluating public policy decisions. Executive Orders 12044, 12291, and 12866 by Presidents Carter, Reagan and Clinton have all mandated economic impact analyses of all significant Federal Regulations (Viscusi, 2003). Initially, values were arrived at considering factors such as lost work hours and medical costs. This approach was used to review the benefit of implementing Occupational Safety and Health Administration's (OSHA) Hazard Communication regulation in 1982. The Office of Management and Budget (OMB) rejected the regulation on the basis of costs exceeded the benefits. OSHA disagreed with this; thinking that the benefit (the value of a human life) was too sacred to put a value on, and appealed to then Vice-President Bush. Harvard Law School professor, W. Kip Viscusi, was consulted to settle the disagreement between the two agencies. Viscusi used a different approach to determine the value of life: the Value of Statistical Life (VSL) methodology. Using this methodology, the value of life is increased by approximately an order of magnitude. With a new value, the Hazard Communication regulation was passed (Viscusi, 2003). Subsequent economic analyses have continued to use the VSL methodology.

The actual value of the VSL was determined by taking the mean of 26 different economic studies; the EPA arrived at a VSL of $6.3 million dollars per person adjusted to the year 2000 (Viscusi, 2003). Other VSLs are used by different organizations for economic studies; however, since the EPA is responsible for the most costly Federal rule-making in the U.S. government, the EPA number is used in this study (Viscusi, 2003).

Using the EPA VSL of $6.3 million and Wein's model's estimate of between 100,000 and 700,000 deaths (depending upon antibiotic supply and distribution) from an anthrax attack with a response initiated at 48 hours after release, the societal economic cost would be between $6.30 x 10^{11} and $4.41 x 10^{12} (or $630B and $4.41T). This is the cost associated with the expected mortalities due to a release of 1 kg of anthrax concentrated at 1 trillion spores per gram in a city of 10 million people with no biosurveillance measures in place.

BioWatch Benefit – Cost

The societal benefit of surveillance, specifically BioWatch, is difficult to establish. First, the cost of establishing surveillance has to be determined. No specific quotes have been published, but estimates have been made. Shea reports that the initial investment for a city is approximately a $1M dollar capital cost, with an additionally $1M per year required for operation and maintenance costs (Shea, 2003). This is a conservative figure; higher costs have been estimated. Probably the most accurate figures come from communication with Dr. Jeff Stiefel, Program Manager for BioWatch with the Department of Homeland Security. Stiefel stated that Fiscal Year (FY) 2003 funds allocated for the program were $60M; these funds were for the start-up of the program in approximately 31 cities (Stiefel, 2005). FY 2004 and FY 2005 allocations were $38M and $60M, respectively; these investments cover day-to-day operations (Stiefel, 2005).

Consider this cost of providing surveillance with the reduced number of mortalities expected. The advertised capabilities of the BioWatch system are to detect and confirm the presence of biological agents within 36 hours of a release (Emory, 2005). Stiefel communicates the ability to know of an attack is within 27 – 36 hours. What reduction in severity can be expected due to a shift from 48 hours in the model developed by Wein to the 27 to 36 hours response expected if BioWatch is in place? Wein reports that his model does not predict a markedly reduced number of deaths by rapid detection: if the detection delay is reduced to 6 hours after release, 70,000 deaths can still be expected (down for 100,000 with a 48 hour detection time) with optimal distribution of antibiotics (Webb, 2003). Conversely, for the same "optimal pharmaceutical distribution" scenario, a detection time of 4.8 days (115.2 hours) causes the model to predict a doubling of the number of deaths from 100,000 to 200,000 (Wein, 2003). Wein's data points are plotted in Figure 11 below.

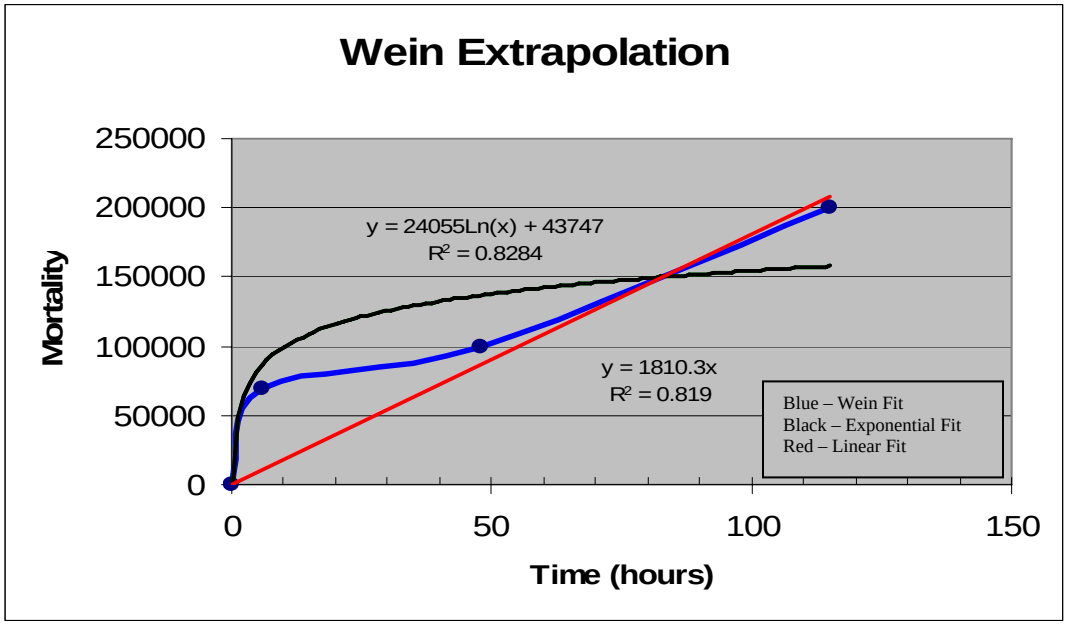


Figure 11 –Dr. Lawrence Wein's Model for t=6 hours, 48 hours, and 115.2 hours with Logarithmic and Linear Fit Equations (Wein, 2005)

Using these numbers, a response time that is shortened from Wein's 48 hours to the BioWatch advertised time of 27-36 hours would result in an expected mortality of below 100,000 but above 70,000. Fitting an exponential curve to Wein's datapoints, equation (1) results:

$$\text{(eq.1)} \quad y = 24055 \ln(x) + 43747$$

Where "y" represents the mortality number expected and "x" represents the time in hours until response activities are started.

With only three data points, the fit curve has an R^2 value of 0.83. The R^2 value is a coefficient of determination and represents the proportion of the total sample variability around the mean of "y" that is explained by the linear relationship between "y" and "x" (McClave, 2005). R^2 is sometimes referred to as a "goodness of fit"; the higher the R^2 value, the better fit between the model (fitted curve) and the data. An R^2 value of 0.83 is not particularly high, however, a linear equation fit to Wein's data points, yields equation (2) with a very similar r^2 value of 0.82. Equation (2) is given below:

$$\text{(eq.2)} \quad y = 1810.3 (x)$$

Where "y" again represents the mortality expected and "x" represents the time in hours until response actions are undertaken.

Epidemic curves of disease often present in logarithmic fashion; additionally Wein's model assumes a log-normal incubation period. Without a significant improvement to the goodness of fit using a linear best-fit line, the logarithmic equation is the preferred modeled equation. Simplifying this, two of Wein's datapoints are acting as boundary conditions to the times of interest in this paper. Stated otherwise, Wein's model was run for 4 hours and 115.2 hours; the mortalities of interest in this paper are included within this range. Therefore, picking points directly off of the Wein curve is the easiest, most accurate, and therefore, the preferred method available.

The arithmetic mean of the BioWatch response time range is 31.5 hours. Using this value for "x," the expected mortality number is 86,600 deaths. The economic severity associated with this number is $\$5.46 \times 10^{11}$ ($546B). This is an economic savings of $84B when compared to the $630B in economic costs predicted when having no biosurveillance system in place.

The net returns from a biosurveillance system can be quantified by subtracting the cost of surveillance from the savings averted in the population. Equation (3) represents this as:

(eq.3) Net Returns = Savings from Costs Averted in Population – Cost of Surveillance

Using the numbers above, the net returns for the BioWatch surveillance system for the anthrax scenario described is a savings of $84B minus a negligible start-up and operation and maintenance costs (Shea's numbers are $1M and $1M, respectively; Stiefel's numbers are $1M and $2M, respectively – all of which are negligible when subtracted from the savings of $84B). Therefore, the net savings provided by an established and operational BioWatch system in city where 1 kg of anthrax is released that behaves as modeled by Wein's Gaussian plume is $84B. This analysis is contingent upon an anthrax attack occurring within the first year of providing surveillance; this is not the case.

The accurate statistical likelihood of an anthrax attack is difficult to determine or locate in open source (i.e. not classified) literature. If the attack probability is 1 in a 100 (or one attack in 100 years) or 1 in a 1000 (one attack in 1000 years), the costs averted in equation (2) would be multiplied by 0.01 or 0.001, respectively. Doing so results in a BioWatch net return of $840M if the probability of an anthrax attack is 0.01; net returns for a 0.001 probability event are $84M. The capital, and operation and maintenance costs, are no longer negligible. From an economic perspective, a negative net return occurs when the cost to provide surveillance is greater than the costs avoided by having surveillance in place. In other words, the economic outcome is cheaper when not providing surveillance than when providing it. Conservatively assuming New York City has twice the average number of BioWatch units deployed results in a $2M start-up cost and a $3M annual operation and maintenance (O&M) cost. Using these numbers,

BioWatch system would return a negative net return after 28 years without an anthrax attack.

"A Hot Idea" Benefit – Cost

Considering "A Hot Idea" surveillance, with the same anthrax scenario described and the same likelihood of anthrax attack, would differ in two ways. First, initial costs of the infrared thermal scanning units and their operation and maintenance costs are different. Secondly, different costs would be averted due to an earlier or later notification time than BioWatch's 27-36 hours, thereby producing a smaller or greater mortality number.

The rental cost of infrared thermal scanning units have been quoted at $33,333 per unit, per year while personnel costs to perform operation and maintenance are $350,000 per unit, per year (The Vancouver Sun, 2003). These costs were from the deployment of six thermal scanners at both the Toronto and Vancouver international airports during the SARS outbreak of 2003.

The City of New York employs 40,710 uniformed police and 16,015 fire and emergency medical service personnel (Keilin, 2001). Additionally there are 21,116 postmen who work in the city's five boroughs; 9,107 of them are letter carriers (Mitchell, 2006). The total number of uniformed police, fire and emergency medical service workers, and letter carriers is 65,832. The police department of New York City is divided into 76 different precincts (NYC gov. website, 2005). Each precinct participating

in “A Hot Idea” would require one thermal scanning unit. The fire department has 141 fire stations throughout the city. Each participating fire station would require one thermal scanning unit. Finally, there are at least 131 post office facilities (Donohue, 2004) in New York City, each participating facility requiring one thermal scanning unit. The total number of police precincts, fire stations and postal facilities in New York is 348.

Assuming the commissioned workforce is equally distributed across the city, 50% of the commissioned workforce works from 50 % of the commissioned workforce buildings. Therefore, 174 thermal scanning units are required to provide surveillance to half of the city’s workforce, or 32,916 city personnel. At $33,333 per unit, the annual cost for equipment is $5.8M. The O&M cost for this equipment is $60.9M. Together these figures equal $66.7M for equipment and operation and maintenance costs per year for the city and scenario described.

Similar to the BioWatch calculation, the time to notification needs to be determined to estimate the mortality using equation 1 above. “A Hot Idea” is based upon the idea that an increase in body temperature will be one of the first responses at onset of infection. With an absence of data regarding the sentinel response of the human body after inoculation, consider the epidemiological data.

The epidemiological data for inhalational anthrax is limited and varied. The most recent data is from the 2001 bioterrorist events in the United States. Fever, chills, malaise, and fatigue were the initial symptoms reported in all ten cases occurring in

October and November of 2001 (Henderson, 2002). The range between exposure and onset of symptoms (defined as influenza-like symptoms: fever, chills, drenched sweats, gastrointestinal complaints, headache, cough, and chest pain) for inhalational anthrax during the bioterrorism related attacks of 2001 was from four to six days, with a median of four days (Bartlett, 2002). This is referred to as the incubation period. Defined in the Control of Communicable Disease Manual, "incubation period" is the time interval between initial contact with an infectious agent and the first appearance of symptoms associated with the infection (Chin, 2000). The validity of this 2001 data is not questionable, however the small numbers of patients affected is concerning; there were 11 cases, and data was collected from 10 of the 11. Discounting the 2001 bioterrorism attacks, there have been 18 reported cases of inhalational anthrax in the United States in the last 100 years (Barlett, 2002). Data was not collected or kept for most of these intermittent cases. The Sverdlovsk data is the only other source of epidemiological data of humans but the 1979 Russian anthrax release is clouded with uncertainty. The median duration between exposure and onset of symptoms for the anthrax release the Sverdlovsk, Russian incident in 1979 was 19.5 days (Bartlett, 2002). The data set is larger for the Russian release but its quality is suspect. Meselson reports 68 of the 79 patients with inhalational anthrax died in the incident (Meselson, 1994). Another report says 358 people were ill with 45 dead; another recorded 48 deaths among 110 patients (Henderson, 2002). This variation in reported numbers and the lack of available and timely reports from the former Soviet Union brings the quality of data into question. Other reliable sources for anthrax information are the Control of Communicable Diseases Manual, by the American Public Health Association (APHA) and the USAMRIID Blue Book, by the

United States Army Medical Research Institute for Infectious Diseases. These books quote incubation periods for anthrax to be between 1 – 6 days and 1 – 7 days, respectively (Chin, 2000 and USAMRIID, 2004). The Blue Book footnotes their incubation period with a note: "During an outbreak of IA [inhalational anthrax] in the Soviet Union in 1979, persons are reported to have become ill up to 6 weeks after an aerosol release occurred. Studies performed in nonhuman primates confirm incubation periods which can be up to 100 days" (USAMRIID, 2004).

The varying reported incubation periods make a singular choice difficult. Using the median incubation time from the 2001 attacks is one approach. A 4 day incubation period is greater than the 48 hours Wein used in his model which generated a mortality of 100,000. Reading the ordinate off of Wein's curve at 96 hours gives a mortality of 172,000. Using the EPA's VSL (value of statistical life) of $6.3M, the cost associated with this expected mortality is $1.08T. This is $450B more than the fatalities expected from Wein's output using his time from release to response of 48 hours. Therefore, only considering a 4 day response, Wein's model as the basis for comparison, and considering optimal pharmaceutical distribution, the costs associated with implementing "A Hot Idea" do not return a positive net return. These scenario details however, would probably not unfold in such a manner. At some time before the median incubation period, some portion of personnel enrolled in "A Hot Idea" would present with an elevated temperature and identify the need for further investigation.

The term “symptom” is used to describe a condition reported by the patient. A “sign” differs from a “symptom;” a sign is a physical finding made by a physician. Although all 10 patients experienced the symptom of a fever, only 7 of the 10 patients had signs of a fever above 37.8°C. This is an important distinction. Although the 2001 bioterrorism attacks are a small data set, if “A Hot Idea” was looking for temperatures above 37.8°C, 30% of those infected would be missed. In this case, workforce personnel should be told to report to the “workplace clinic” if they are feeling feverish regardless of infrared temperature measurements.

Alternatively, considering the more realistic lower range of the incubation time of 1 day results in an expected morality of 84,300. The ranges cited by both USAMRIID and the APHA are 1 - 6 and 1 - 7 days, respectively. This equates to a cost avoidance of $99B. As was done for the BioWatch analysis above, this savings of $99B is true if an anthrax attack is certain within the year being considered. This is not the case and is difficult, if not impossible, to determine the likelihood of an attack.

If the attack probability is 1 in a 100 (or one attack in 100 years) or 1 in a 1000 (one attack in 1000 years), the costs averted in equation (2) would be multiplied by 0.01 or 0.001, respectively. Doing so results in “A Hot Idea” net return of $990M if the probability of an anthrax attack is 0.01; net returns for a 0.001 probability event are $99M. Considering a rental and O&M cost of $66.7M per year, “A Hot Idea” would yield a negative net return after 15 years without an anthrax attack if the probability of

attack is 0.01. A negative net return would result after two years if an attack whose likelihood is 0.001 did not occur.

The early estimates of fever from USAMRIID and the APHA are 24 hours. This time seems reasonable because a portion of a monitored workforce will be present with fever in this early period of disease progression. If this time could be shortened even further, the benefit of "A Hot Idea" would increase again. Assuming a 12 hour response time due to the specificity garnered by developed individual temperature profiles is not unreasonable. At 12 hours, the expected mortality is 77,100. Savings are $1.44B and $144M for 0.01 and 0.001 probability events. Considering the same rental and O&M cost, "A Hot Idea" yields negative net returns after 22 years and 3 years for 0.01 and 0.001 probability events.

Limitations of Data

Some issues with the quality of the data behind these economic numbers have been mentioned previously (e.g. Sverdlovsk data reliability, small sample sizes, etc.). Although tractable and well-referenced, the economic analysis is heavily dependent upon Wein's model and limitations of modeling must be considered. Although the difference between a detection time of 6 hours and 48 hours was stated as "not markedly different," it can be argued otherwise. The difference between 70,000 deaths and 100,000 deaths is 30,000 deaths; this is still a magnitude of death averted that deserves significant consideration and appreciation. The quantity, or availability, of data should also be addressed. There is a lack of available data for a variety of reasons.

BioWatch Data Limitations.

BioWatch surveillance is a sensitive subject; specific agents screened for, locations of surveillance, and the scheduled time intervals between analysis of samples are all closely-held information for obvious reasons. The cost to maintain and operate BioWatch is also difficult to accurately quantify because budget numbers for biodefense are not broken out by methodology but rather by the specific Departments of the federal government that operate the methodologies. Within these departments, data is further clouded by categorizing line items with vague headings. For example, The Department of Homeland Security combines their budget numbers for BioWatch with the Homeland Security Advanced Research Projects Agency (HSARPA) initiatives and "other" research efforts. The line item in their published budget data combines these efforts under "Biological Countermeasures;" finding further breakdown is difficult.

"A Hot Idea" Data Limitations.

Data for "A Hot Idea" also presented a challenge to obtain. This methodology has not been fielded to date and system set-up, maintenance, and operation costs have to be estimated from *similar*, but still *different* technologies - like those used during the 2003 SARS season. One difference to consider is the high cost associated with the rental of equipment and hiring of expertise to maintain and operate the thermal scanning units. If "A Hot Idea" were to be implemented, a comparison would have to be made between the cost to lease and the cost to purchase outright. Additionally, the costs quoted here were during the SARS outbreak of 2003. Anytime technology is quickly implemented to

address an urgent need, elevated costs will result. Competition and economies of scale would bring thermal scanning units down on a cost/unit basis.

Morbidity Considerations

The discussion thus far has focused on the societal costs associated with mortality. The illness rates, or the morbidity, associated with a similar scenario also warrants discussion. For the base case used in Wein's model, 1.49 million people will become infected with the 1 kg anthrax release in climatic conditions described in his paper. These infected people would require treatment and require services from the medical apparatus of a city. This volume would quickly overwhelm the medical apparatus. Output from Wein's model agrees with this statement. Additionally, a classified exercise run by the U.S. government in the fall of 2003 further confirmed this (Wein, 2005). On top of this the "worried well" presenting to the medical facilities would have to be dealt with. To satisfy the capacity that would be required by the medical system, a 75-fold increase in facilities would have to be put into place for the Wein scenario (Wein, 2003). This type of increase in care cannot be practically resolved but must be addressed in response plans and planned for accordingly.

From an economical benefit-cost standpoint, morbidity costs are not expected to have a major impact on the overall societal costs. Therefore, market-based values were not assigned to quantify the effects of morbidity on society in this study. However, this assumption of lower economic morbidity effects, should be investigated with further research.

Emerging Infectious Disease Considerations

The data presented here deals with one anthrax scenario. As discussed, many variables could be altered creating a different result. The environmental conditions, the timeliness of antibiotic distribution, and the efficacy of pharmaceuticals are just three examples that, when changed, could produce significantly different effects and mortality numbers. Additionally, if the incident were terrorist in nature, the technological capabilities and intelligence of the attacker would influence the severity of the attack. Keeping all the scenario variables constant, save one: the biological agent considered, has the potential to change the outcome to an even greater extent.

The potential economic severity presented by a pandemic strain of avian influenza virus was discussed earlier. An economic analysis was not conducted in this study due to the scope of this work and the limited data available about a potential pandemic strain of this virus that has not yet emerged. Follow-on research could explore this subject further. Some considerations of surveillance for avian influenza and other emerging infectious diseases are discussed in the analysis section of this work.

Chapter 4 – Results and Analysis

Comparative Benefit – Cost Findings

While the data was difficult to obtain, a comparative economic benefit – cost analysis was performed for a scenario involving anthrax. The anthrax scenario was modeled by Lawrence Wein, *et al*.; and although peer reviewed, his work is still a *model.* A model with a different construct, or with different assumptions, would have resulted in a different output which could yield a different outcome in this effort. With these limitations noted, the benefit-cost analysis yielded a societal savings of $84B in the event of an anthrax attack behaving according to Wein's model. Including the operation and maintenance cost, and assuming a probability of such an attack at 0.001, BioWatch represents a positive benefit-cost for 27 years. A time period greater than this, without an anthrax attack but with BioWatch continuously operating is not economically justifiable. The benefit-cost analysis for "A Hot Idea" with a 12-hour response time yielded a societal savings of $144B in the scenario predicted by Wein's model. Although this is a greater cost averted, the cost of surveillance is also greater for "A Hot Idea." The greater operation and maintenance cost makes "A Hot Idea" economically justifiable for two years assuming the same 0.001 probability of anthrax attack. Stated differently: a period without an anthrax attack greater than two years would result in a benefit-cost figure less than one and not be considered economically justifiable.

Additional Considerations

Some of the differences in the two methodologies are not considered in this analysis. The geographic area and the volume of air monitored by each methodology were not considered. The vague numbers of samplers and lack of specific location information in the BioWatch construct makes an accurate number difficult to tabulate. Sampling units are deployed to cities with larger populations and greater likelihood of receiving a malicious biological release. Specific detector locations are assumed to be based upon predominant meteorological conditions. Shifting or abnormal weather patterns may jeopardize optimal placement of the air sampling BioWatch units. Additionally, microclimates are not always well-understood in urban environments; strange air movement patterns exist between and around large high-rise buildings. Optimal sampling locations in these atypical conditions are difficult to achieve all of the time.

Sample Volume.

One way to compare the coverage provided by the two methodologies is to consider the volume collected by each system. "A Hot Idea" will conduct surveillance on ½ of the commissioned workforce of New York City, or 32,916 city personnel. The average person at rest consumes 6 liters of air per minute (L/min) (Fox, 2004). During heavy exercise, this consumption rate can increase to 100 – 200 L/min (Fox, 2004). Conservatively using the 6 L/min rate, each person will "sample" 360 liters of air per hour, or 8640 liters per day. With the workforce of 32,916, that equates to 284,394,240 liters of air per day or 284.39 million liters of air per day. In the event of an emergency

response, the rate of 6 L/min would significantly increase and thereby significantly increase the overall sample volume collected. A high-volume air sampler, such as those used with BioWatch, can collect between 700 and 1500 L of air/min (Kimoto-Electric website, 2006). This equals a volume of 2.16 million liters of air per day per sampler. Using the volume collected by "A Hot Idea" participating personnel equates to more than 131 high-volume samplers for New York City. BioWatch, on the other hand, has been estimated to have 500 air samplers working in 31 cities (Kosal, 2003), or an average of slightly over 16 air samplers per city. New York City is the largest city in the United States. Assuming twice the average number of samplers exist in New York City would equate to 32 air samplers. The volume collected by 32 high-volume air sampling units is 69.12 million liters of air per day. These volumes are shown graphically in Figure 12.

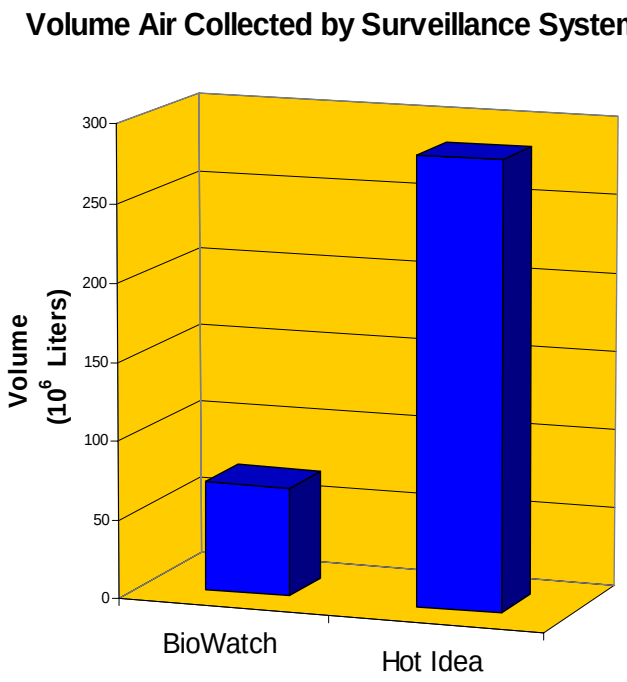


Figure 12 - Volume Air Collected by Surveillance System. Assumes "A Hot Idea" workforce of 32,916 and 32 BioWatch Samplers operating in New York City.

Some consideration should be made for this disparity in sampling volume. Using the numbers above, "A Hot Idea" collects over four times the volume of air that BioWatch does. If New York City had three times the average number of sampling units compared to the other cities enrolled in BioWatch, the volume collected (103.68 million liters/day) would still be less than half that collected by "A Hot Idea."

Normalizing to reflect an equal volume of air sampled would require a workforce approximately 25% the size used in the calculations above. "A Hot Idea" workforce of 8000 personnel consuming 6 L/min would sample approximately a same volume as 32 BioWatch units. The reduced workforce would require a proportionally smaller amount of thermal scanners. The rental and O&M cost of 42 thermal scanning units is $1.4M and $14.7M, respectively. Using these numbers a negative net return would result after nine years if an attack whose likelihood is 0.001 did not occur. Table 6 shows the normalized results compared to the "No Surveillance", "BioWatch", and "A Hot Idea" scenarios described previously.

Table 6 - Time to Negative Net Return for Different Biosurveillance Methodologies if Probablitly of Anthrax Attack is 0.001

Methodology	Capital Cost	Annual O&M Cost	Neg. Net Return w/ 0.001 event probability
No Surveillance	$0	$0	-
BioWatch	$2M	$3M	28 years
"A Hot Idea"	$5.8M	$60.9M	3 years
"A Hot Idea" (equal vol sampled)	$1.4M	$14.7M	9 years

"Design-To" Cost for "A Hot Idea"

Thus far, analysis has shown BioWatch to outperform "A Hot Idea" on the basis of "time until negative net return". Negative Net Return is dependent upon equation 3 above. The two components of equation 3 are the "Costs Averted" and the "Cost of Surveillance". "Costs averted" are similar between the methodologies but there is a vast difference in the "Cost of Surveillance." As stated previously, thermal scanner costs quoted in this analysis were those seen during the SARS outbreak of 2003. Rental costs from the 2003 actions were used because these financial figures were available in the literature. The O&M cost came when the technology was rather new and in high-demand. These costs would be reduced with greater competition and economies of scale if "A Hot Idea" were implemented in multiple cities. The extent of cost reduction necessary to achieve the same negative net return time period as BioWatch was determined.

Purchasing the thermal scanners, as opposed to renting them, is a realistic decision that would likely occur with the fielding of a multiple city deployment of "A Hot Idea". A one-time capital cost of $1.4M would require an annual O&M cost of $5.1M. These figures result in a negative net return at the same time as BioWatch. These "design-to" figures are shown in the last row of Table 7.

Table 7- "Design-To" Costs for "A Hot Idea" Resulting in Equal Time until Negative Net Return. Note purchase price for thermal scanners replaces rental costs.

Methodology	Capital Cost	Annual O&M Cost	Neg. Net Return w/ 0.001 event probability
No Surveillance	$0	$0	-
BioWatch	$2M*	$3M	28 years
"A Hot Idea"	$5.8M**	$60.9M	3 years
"A Hot Idea" (equal vol sampled)	$1.4M**	$14.7M	9 years
"A Hot Idea" "Design-To" calculation	$1.4M*	$5.1M	28 years

*One-time purchase price
** Annual rental price

Mobile and Stationary Samplers.

"A Hot Idea" samplers are mobile samplers while BioWatch's are stationary. By being mobile, a larger surface area of the city is covered. Participating personnel travel inside buildings, on public transportation, and move throughout the day under, above and on the pavement of the city. A larger variety of conditions are encountered by "A Hot Idea" personnel. This was not considered in the economic analysis.

Anthrax versus Other Agents.

This comparison evaluates the different methodology's performance in the context of an *anthrax* attack. Neither of the respective surveillance technologies was developed for the sole purpose of detecting the next anthrax attack. BioWatch is an early-warning detection system looking for the presence of harmful biological agents in the cities where the system is operating. A finite number of agents are looked for; the exact number is unknown but can be confidently stated that agents other than anthrax are

screened for. "A Hot Idea" also looks for more agents than just anthrax. In fact, it could be said that "A Hot Idea" looks for *many* agents that have potential to infect large portions of society. This is one of the stronger advantages to "A Hot Idea."

"A Hot Idea" will theoretically find any agent that causes a statistically significant portion of a participating workforce to result with an elevated temperature. In addition to finding Category A agents such as anthrax, plague, and tularemia, "A Hot Idea" will identify biological agents that cause "regular" public health problems such as seasonal influenza. Finally, "A Hot Idea" will identify emerging infectious diseases that are new, and perhaps even unknown, at their time of presentation. An avian influenza with the capability of human-to-human transmission – not proven to exist at the time of this writing – might be an example.

The ability to find any agent is based on the idea that an actual human being is being used as the sensor to identify biological agents that will harm human beings. This cyclical detection relationship is what allows detection of infectious agents that cause a spike in temperature. Developing a collection technology as exquisite and accurate as the human immune system is difficult, if not impossible.

Pathophysiology of Elevation in Temperature

"A Hot Idea" considers elevation in temperature as one of the initial signs after the foreign agent enters the body. Disease progresses in stages starting with the incubation period. The incubation period is defined as "the time from the moment of

inoculation (exposure) to the development of the clinical manifestations of a particular infectious disease" (Pharma-Lexicon.com, 2006). The next stage or phase of disease is called the prodromal period. The prodromal period is defined as "time during which a disease process has begun but is not yet clinically manifest" (Pharma-Lexicon.com, 2006). The prodromal period is the short interval between the incubation period and illness; the beginning appearance of symptoms (subjective) when the patient is getting sick but without clinical signs (objective) being evident. Following the prodromal period is the period of illness, then the acme (the height of illness), decline, and finally resolution (Abedon, 1998).

The first two stages of disease are those that "A Hot Idea" is concerned with; the incubation and prodromal periods. Does the body respond by increasing temperature before other clinical signs and symptoms are evident? If so, can "A Hot Idea" find this temperature increase before the disease is clinically manifest?

The hypothalamus is the region of the brain that regulates temperature. In addition to maintaining the normal, homeostatic temperature of the body, the hypothalamus is also capable of raising the "set temperature." When fighting an infection, the body benefits from a elevation of temperature. A rise in temperature makes the body less hospitable to bacteria. Additionally, increases in baseline temperature boost immunity to viral agents by releasing interferons. Interferons are "a family of proteins derived from human cells which normally has a role in fighting viral infections by preventing virus multiplication in cells" (Pharma-Lexicon.com, 2006).

To induce a rise in temperature, the hypothalamus increases the body's baseline temperature. The pathophysiology involves pyrogens (proteins) that start a cascade of events that eventually raise the body's baseline temperature and produce an elevation in temperature and eventually, a fever. Generally there are two types of pyrogens: exogenous and endogenous. Exogenous pyrogens come from foreign agents in the body, notably microbial cells or toxins. Endogenous pyrogens are host cell-derived cytokines, usually from macrophages. Cytokines are signaling molecules, similar to hormones (Pharma-Lexicon.com, 2006). The metabolites of exogenous pyrogens induce the production of endogenous pyrogens. The process by which these pyrogenic cytokines cause elevations in temperature is not completely understood. The cytokines may interact with each other or with metabolites of cytokines, cross the blood-brain barrier to reach the thermal regulating center of the hypothalamus region triggering another set of events increasing one's baseline temperature (Prewitt, 2005; Merck, 1999). This new baseline temperature is maintained using the same negative feedback loops that maintain a normal temperature in a healthy body.

Data Management and Individual Temperature Profiles

The data management piece to "A Hot Idea" is crucial to the success of this methodology. Developing an accurate temperature profile for each participating individual in the program is imperative to avoid confusing a rise in temperature with the daily undulation expected due to circadian rhythm fluctuations.

Defining the average body temperature as 37°C, an elevated temperature as anything above 37°C, and a fever as > 38°C, is an incorrect assumption for "A Hot Idea" purposes. First the numbers above are for an entire population, not an individual. Second, standardized methods were not adhered to in the past: times of day, indoor temperatures, ovulatory status, calibration of thermometers, and placement of the temperature measuring devices were some variables that were not kept constant. With a better knowledge of physiological mechanisms the body uses to regulate temperature, a better understanding of hormone interaction and cellular metabolism, and having calibration techniques for thermometers, a more accurate normal range can now be defined. Individual temperature profiles with greater specificity will be developed using controlled methodology to use with "A Hot Idea."

Body temperatures vary both within a particular individual and within the general population. In an individual, the temperature variation is due to circadian rhythm, and is about 0.6°C (1°F) (Merck, 1999). The nadir, or low point is 6 AM and the zenith, or high point, is between 4 and 6 PM (Mackowiak, 1992). A study looking at adults aged 19 to 59 years reported an average ear temperature range of 35.0°C to 37.8°C (Sund-Levander, 2004). Mackowiak's work found 36.8°C as the mean oral temperature of subjects, higher temperatures for women than men, and a trend of higher temperatures in African-Americans than in Caucasians (Mackowiak, 1992). Body temperature is also dependant upon the ovulatory cycle in women; when ovulating, body temperatures increases by ~0.3°C (Craig Medical Distribution, 2006). Post-menopausal women have lower temperatures than menstruating women; more similar to the men's range (Sund-

Levander, 2004). These results are all normalized to reflect the range of temperature to the average person in the average environment. Altering the individual's physical environment will provide further variation to the normal range.

One's physical state of health has to be considered. The state of health should be considered in two ways – versus the general populace and versus the normal state of physical health for that individual. First, compared to the populace, those with lower body mass indices have less fat to insulate the body with and therefore have lower normal temperatures. Similarly, because women generally have a larger amount of subcutaneous fat than men, this is one mechanism that contributes to women having higher temperatures than men. Lower resting heart rates and higher metabolic levels will also affect temperature levels. Addressing the second consideration, a person's current state of health compared to their normal state of health, an individual's body temperature fluctuates with the level of exercise, stress, and hydration (DiscoveryMedical.com, 2005). Temperatures fluctuate due to metabolic activity and therefore the diet of individuals should be considered (e.g. an individual's temperature will vary depending upon when a meal was eaten last - 30 minutes ago or 5 hours ago). Variables affecting the temperature are numerous. A well-thought out data management system will be needed to resolve these issues.

Individual temperature profiles will need to be developed for each participant in "A Hot Idea." A "baselining" period of some time (e.g. 6 to 12 months) will be needed to create a unique temperature profile with statistical merit. This baselining period may

have to be longer for women in the program as they normally experience a greater amount of variation in their temperatures due to ovulatory cycles.

Ease of use for the participants of "A Hot Idea" should also be considered when designing the data management and collection process. Thermal scanners have advertised needing a measurement time of 3 seconds to accurately record and report temperatures. A "user-friendly" procedure is crucial to gain acceptance of the new surveillance methodology.

Does diurnal variation occur in the presence of fever? During a 24 hour period, temperature varies from lowest levels in the early morning to the highest levels in the late afternoon. Overall however, there is a lack of temperature measurement data conducted in a standardized manner. Individual temperature profile data collection and management is addressed again in the follow-on research section of the next chapter.

Chapter 5 - Discussion

This research effort compared different biosurveillance methodologies using a benefit – cost deterministic model. A currently fielded air sampling system, BioWatch, was compared and contrasted to a thermo-detection methodology called "A Hot Idea." A "do-nothing" approach was also considered. Available information regarding the methodologies was limited and therefore, there was a lack of concrete data to analyze with the benefit – cost approach. However, several observations, considerations, and further research areas were identified.

Biopreparedness initiatives are a complicated and complex issue. The scientific and rational answer may not be implemented due to political pressures and public understanding of the issues at hand. Some studies have concluded that, in the case of anthrax, pre-event vaccination efforts are the most important initiative (Wein, 2005). Others have cited rapid pharmaceutical distribution after an attack as the critical effort to avert societal impact from a biological release (Kaufmann, 1997). This research did not focus on either of these ideas. In reality, a combination of systems will be implemented to address the need for readiness against harmful biological agents. One of these systems is biosurveillance. BioWatch is currently operating in 31 cities across the country. "A Hot Idea" is another surveillance methodology that should be considered further. The political backlash associated with a "do-nothing" approach makes this option unlikely. Allocating resources from biosurveillance to other initiatives such as a vaccination or antibiotic distribution program could be considered but was not undertaken here.

Modeling with one biological agent and one set of environmental conditions, BioWatch was found to be more economically beneficial than "A Hot Idea." With a likelihood of anthrax attack set at 0.001, BioWatch returned a positive benefit – cost ratio for 27 years while "A Hot Idea" returned a positive benefit – cost ratio for three years.

Comment on these results should be made. "A Hot Idea" collects multiple volumes of air more than that collected by the high-volume samplers used in BioWatch. When adjusted to an equal volume of air, "A Hot Idea" returned a positive benefit – cost ratio for eight years. The sampling personnel for "A Hot Idea" are mobile and cover a lager area of a city including outdoor and indoor environments. Sampling a larger volume and covering a larger surface area provides a more thorough surveillance of a city for harmful biological agents. BioWatch screens for a limited number of agents where "A Hot Idea" looks for any and all agents that will cause an elevation in temperature. The "any and all" includes both presently existing microbes and unknown organisms that may emerge in the future.

The potential capabilities of "A Hot Idea" are enormous. If the enabling technologies can be developed supporting the "A Hot Idea" methodology, "A Hot Idea" is the better of the two choices. The enabling technologies need to be fleshed out and their feasibility determined. The data management of individual temperature profiles will need to be specific enough to recognize small incremental deviations from the person's average temperature taking into account metabolic fluctuations and different activity

levels. Better pathophysiological understanding of the earliest time in the elevation in temperature needs to be determined - long before a defined fever of 38°C is reached. Understanding of the mechanisms at work during the initial generation of pyrogens is crucial. If pyrogens are not created or do not interact with the hypothalamus during the incubation period and only begin during the short prodromic period, a fever mechanism will not be triggered and therefore, will not be picked up by "A Hot Idea" regardless of the specificity within individual temperature profiles.

An advantage of "A Hot Idea" is the ability to detect a great number of today's present biological agents and tomorrow's emerging infectious agents. The cornerstone of this is the temperature increase in the human body. Anthrax, plague, tularemia, and smallpox all have *prodromic* fevers; Venezuelan equine encephalitis and Q-fever have fever associated with the *illness period* (USAMRIID, 2004). Individuals infected with brucellosis experience an undulating fever. An individual exposed to malaria on the other hand, may not present with a fever for months. Arguably malaria isn't generally considered a biowarfare agent of concern but the issue is with the body's different response to different agents. An emerging infectious disease that does not produce an early fever would be problematic to "A Hot Idea." BioWatch would also have problems with an emerging infectious disease but for different reasons; because BioWatch is only looking for a list of expected agents.

Finally, the capability of physicians and medical laboratories to be able to identify any agent infecting the human body needs further exploration. The differential diagnosis

by today's physicians does not include emerging infectious diseases that have not been previously identified. The outbreak of hantavirus in the four corners region of the United States in 1993 was not recognized for almost a month (Zubay, 2005). The time to arrive at the correct diagnosis should be studied to accurately estimate the time until response activities are initiated.

Follow-on Research

Disregarding the limitations due to available data, several limitations and unknowns were discovered for each respective biosurveillance methodology. These limitations could be researched in follow-on studies.

Morbidity Study.

With more solid data, follow-on research efforts could focus on the morbidity aspect of a biological release. Viscusi's Value of Statistical Life (VSL) figure of $6.3M is considered the standard for policy decisions today. Using this value to compute societal costs for mortality is well founded. Finding a similarly accepted figure or methodology to calculate morbidity costs is more difficult. Without a thorough effort to define well-founded economic values for morbidity, quantifying societal costs would only add more uncertainty and therefore was not undertaken during this study. Follow-on research efforts could look into the impact morbidity plays on society cost. Patients could be classified into three categories: in-patient hospitalizations, out-patient hospital visits, and those not seeking medical care. The groups could then be further divided into age groups: 0-19, 20-64, and over 65 years to further delineate the impact missed time

from work and family would have on the society. These costs could then be added to the mortality piece that was completed in this paper for an overall, morbidity *and* mortality cost to society.

Individual Temperature Profiles.

The general concept behind "A Hot Idea" is attractive at first glance. Unknowns that need to be resolved to discern the full potential of the idea are many. Can the sensitivity of current temperature measuring devices be reduced to flag the first sign of infection? Temperature measurement is done today in terms of distinguishing a fever from a non-fever. This thought process will need to be changed with "A Hot Idea" into one that looks for the earliest rise in temperature due to the presence of a pathogen. Today's temperature measurements are interpreted using the variation of the general population. Doing so introduces the standard deviation for the general population which includes a wide variety of variables. Different genders, ethnic backgrounds, ages, states of health, and environments are all covered by the accepted average and febrile temperatures of 37°C and 38°C, respectively. These are only a few of the examples that affect temperature variation in a population. For "A Hot Idea" to effectively work, *individual* temperature profiles will have to be built for each worker participating in the program. How much does intra-species temperatures vary from day to day? How much does an individual's level of activity affect their individual temperature profile? Limited studies were found in the literature regarding studies of intra-species temperature variation. Those studies that were found had a low number of subjects (Wouter, 2002).

A follow-on research effort could establish individual temperature profiles and determine the standard deviation observed intra-species. If conducted with personnel attending the Air Force Institute of Technology (AFIT) in Dayton, Ohio, a rather stratified population would be evaluated. Personnel enrolled at AFIT are required to meet certain physical fitness standards and are generally at an age that would be representative of the workforce that would be monitored with "A Hot Idea" methodology. Details preceding the measurement of temperature could be recorded. Examples could include: level of activity individual was involved with, time since last meal, contents of the last meal, and environmental temperatures and conditions the individual recently worked in.

The initial concept of "A Hot Idea" involved the monitoring of pre- and post-workshift temperatures. One requirement is to minimize the standard variation of the individual being monitored so that the earliest onset of illness can be recognized. Individual temperature profiles are one solution to achieve this, but at the same time, the variables that individuals undergo each day may introduce a larger day-to-day temperature variation than desired. If the variation is found to be too great due to changing everyday conditions (e.g. outside temperature, level of exertion at work, details with diet, etc.), "A Hot Idea" might sacrifice some detection time to tighten the standard deviation seen in individual profiles. Temperatures could be collected only once per day. They would be taken initially in the morning before workshifts begin, just after rest has concluded, and when the body is closest to its true state of homeostasis. This would

eliminate some of the variables influencing temperature introducing large amounts of standard variation into the measurements.

Pyrogen Physiology.

Related to the study of individual temperature profiles, the presence and interaction of pyrogens could be looked at further. Using the blood of horseshoe crabs, *Limulus* amoebocyte lysate assays have been developed to ensure the absence of endospores (which are a form of pyrogens) in sterile environments. More medically related in research, valuable information pertaining to the onset of fever and the cornerstone of "A Hot Idea" could be obtained.

Radio-Frequency Identification.

Data management systems will have to be developed to efficiently handle the large amounts of data. Streamlining the process to the most "user-friendly" configuration will help with acceptance of the methodology. Radio-Frequency Identification (RFID) technology should be explored to assist with this. The potential for RFID is just being realized. One example could include coding data onto grain-sized media for identification purposes. This is the same technology used to identify consumers with ExxonMobil's SpeedPass system at fueling stations (Technovelgy.com, 2006). Easy identification of "A Hot Idea" personnel could be enabled when checking in and out from the work environment with RFID. Next-generation RFID could have even greater implications on "A Hot Idea": a RFID device could be inserted into individuals to track

their temperatures. Real-time temperature data would eliminate the use of thermal scanners and provide enormous amount of data to monitor for anomalies.

Conclusion

Providing surveillance for harmful biological material is a complex and difficult task. No panacea exists satisfying all requirements and a combination of initiatives is required to maximize biological readiness. The two methodologies looked at in this paper each have separate strengths, limitations, and challenges. The currently operational BioWatch is providing some level of protection today. Past operating procedures in the event of a positive response, unknown background biological agent concentrations, and a limited list of agents screened for are challenges to the system. Conversely, while not yet fielded, the proof-of-concept behind "A Hot Idea" is attractive but needs further research to determine the practicality of overcoming the challenges mentioned in this paper.

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Vita

Captain David M. Kempisty graduated from Oscoda High School in Oscoda, Michigan in 1991. He entered shortly thereafter into undergraduate studies at Michigan Technological University in Houghton, Michigan where he graduated with a Bachelor of Science degree in Environmental Engineering in May 1996. After a slight respite to the mountains with his bicycle, he was commissioned as a 2nd lieutenant in the USAF as Bioenvironmental Engineer (BEE) in January 1997.

His first duty assignment was at Pope AFB, NC where his luck afforded him the opportunity to serve as the base BEE for a 6 month period. In July of 1999, he PCS'd to Tyndall AFB, FL where he performed acquisition officer duties as a contracting officer's technical representative within the Air Force Research Laboratory's Materials and Manufacturing Directorate. Three years later, Capt Kempisty was stationed overseas at Incirlik AB, Turkey for a 23 month tour. There he served as both the base BEE and the Readiness officer for the 39th Medical Group. At the end of his stay in Turkey, he was accepted into the Graduate School of Engineering and Management at the Air Force Institute of Technology, Wright-Patterson AFB, OH. Capt Kempisty's follow-on assignment will be as an instructor at the School of Aerospace Medicine at Brooks City Base in San Antonio, TX.

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14. ABSTRACT
The purpose of this research is to compare two different biosurveillance methodologies: BioWatch and "A Hot Idea". BioWatch is fielded and operating in major U.S. cities today. Air samples are colected on filter paper and analyzed for the presence of harmful biological agents. "A Hot Idea" is an evolving methodology using the human body's immune response to identify the onset of infection from a harmful pathogen. Detecting a temperature increase, using infrared thermographers, in a statistically significant portion of population would allow earlier identification of a biological release, accelerating initiation of response actions. A selected population including policemen, firemen, and postal carriers, will be monitored for elevations in temperature above previously developed individual temperature profiles. The benefit of surveillance can be quantified economically by determining the costs averted by having surveillance in place minus the costs incurred to provide surveillance. Using a model to determine the relationship between initiation of response actions and magnitude of mortality, each surveillance methodology's benefit was quantified based on expected detection time.

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