SUPERBUGS, RESURGENT AND EMERGING DISEASES, AND PANDEMICS: A NATIONAL SECURITY PERSPECTIVE

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By Frances T. Pilch and
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OVERVIEW

While not often considered, "superbugs" may pose a greater threat to U.S. national security than terrorists or WMDs. Superbugs are those bacteria that have developed immunity to a wide number of antibiotics, and along with emergent and resurgent diseases, and pandemics they may be a greater threats to our population and to the effective functioning of our military.

In the context of globalization, it is difficult if not impossible to contain diseases within national boundaries. International cooperation has become a critical component in addressing world health issues. It is the opinion of these authors that health issues, of necessity, need to be regarded as security issues – security, broadly defined.

Disease has only recently featured prominently in debates on security, and this has likely resulted from a convergence of two new and salient features of security debates. First, transnational threats, such as those posed by terrorist networks, have heightened awareness of the need to control WMD – and biological weapons are clearly in this category. Second, discourse on security has been diversified and has called for an expanded notion of what security means. In particular, the debate calls for including "individual security," as well as the security of territory and the sovereign state.

This article is comprised of three parts. Part One addresses a simple hypothesis: Biological threats may be of natural or deliberate origin, and it is the natural threat that in fact poses the greatest risk to both U.S. forces abroad and domestic security. However, initiatives designed to prevent and detect deliberate disease outbreaks, are critical in detecting and responding to natural outbreaks, and vice versa, if managed intelligently and cooperatively by the involved actors.

Part Two presents three case studies to illustrate some of the concerns raised in Part One: drug resistant tuberculosis, SARS, and avian influenza.

Part Three of this article presents a hypothetical case study modeling the effects of an outbreak of H5N1 on a military base abroad and surrounding communities. The question addressed by this second section is: what do mathematical models indicate concerning the consequences of different potential reaction strategies to disease outbreaks?

INTRODUCTION

While attention concerning U.S. national security is often focused primarily on overt threats, such as those posed by transnational terrorist networks and weapons of mass destruction (WMD) proliferation, in reality, "superbugs" (those bacteria that have developed immunity to a wide number of antibiotics), emergent and resurgent diseases, and pandemics may pose greater threats to our population and to the effective functioning of our military.[1] It is no longer possible

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to look solely at these threats in strictly medical terms, for they have serious political implications and dealing effectively with them is influenced by political constraints. The SARS outbreak provided evidence that domestic policies of governments have an important effect on the spread of diseases across international boundaries. The possibility of the mutation of the H5N1 avian flu virus presents the specter of a global pandemic, and incidences of H5N1 outbreaks have posed a host of questions concerning government capacity, transparency, and veracity in reporting.

In the context of globalization, it is difficult if not impossible to contain diseases within national boundaries. International cooperation has become a critical component in addressing world health issues. The World Health Organization (WHO) is the lead international organization addressing issues of global public health security and has new tools in the form of revised International Health Regulations (IHR-2005), an instrument designed to achieve maximum security against threats from diseases."[2] These new health regulations that bind nations represent a significant departure from the past in that they move away from "passive barriers at borders, airports and seaports to a strategy of proactive risk management. This strategy aims to detect an event early and stop it at its source – before it has a chance to become an international threat."[3]

It is the opinion of this author that health issues, of necessity, need to be regarded as security issues – security, broadly defined.[4] Disease has only recently featured prominently in debates on security, and this has likely resulted from a convergence of two new and salient features of security debates. First, transnational threats, such as those posed by terrorist networks, have heightened awareness of the need to control WMD – and biological weapons are clearly in this category. Second, discourse on security has been diversified and has called for an expanded notion of what security means. In particular, the debate calls for including "individual security," as well as the security of territory and the sovereign state. The debate, incidentally, has been broadened to also include transnational issues such as environmental degradation and transnational crime.[5]

This article is comprised of three parts: Parts One and Two are authored by Frances T. Pilch. Part One addresses a simple hypothesis: *Biological threats may be of natural or deliberate origin, and it is the* <u>*natural*</u> *threat that in fact poses the greatest risk to both U.S. forces abroad and domestic security. However, initiatives designed to prevent and detect deliberate disease outbreaks, are critical in detecting and responding to natural outbreaks, and vice versa, if managed intelligently and cooperatively by the involved actors.* Part Two presents three case studies to illustrate some of the concerns raised in Part One: drug resistant tuberculosis, SARS, and avian influenza.

Compared to the potential death and disruption caused by natural outbreaks of diseases such as HIV/AIDs, tuberculosis, malaria, and emerging diseases, most experts believe that the actual or foreseeable deaths from biological weapons remain relatively small.[6] The microbial world is amazingly changeable – and it is hard for human technology to keep up with its capacity to outmaneuver us! Drug resistance to diseases once believed to be "cured," has grown substantially, and diseases once believed to be confined to a vector or species are demonstrating their ability to jump to other species.

WHO has noted that "the surest way to detect a deliberately caused outbreak is by strengthening the systems used for detecting and responding to natural outbreaks, as the epidemiological and laboratory principles are fundamentally the same."[7] This article will focus on the major program designed to address biological threats, the U.S. Biological Threat Reduction Program (BTRP) and the synergies between the BTRP and defense against natural disease outbreaks. To assess the threat of natural outbreaks of disease, recent cases involving superbugs, resurgent and emergent diseases will then be examined, with an attempt to understand underlying reasons for these incidents and outbreaks and prognoses concerning their importance in risk analysis. The third portion of this article, authored by Kenneth Grosselin, presents a fascinating hypothetical case study modeling the effects of an outbreak of H5N1 on a military base abroad and surrounding communities. The question addressed by this second section is: *what do mathematical models indicate concerning the consequences of different potential reaction strategies to disease outbreaks?*

Part One: Deliberate and Natural Outbreaks

Measures that Address the Biological Threat

Maxim # 1: Measures that are utilized in addressing the threat of deliberate outbreaks of disease are also critically useful in addressing the threat of natural outbreaks, and vice versa. Therefore, they may be viewed as dual-purpose measures.

> The Director-General of the World Health Organization, Margaret Chan, notes that "(t)raditional defenses at national borders cannot protect against the invasion of a disease or vector. Real time news allows panic to spread with equal ease…vulnerability is universal.[8]

There are multiple goals pertaining to programs and initiatives designed to address biological threats. Although different players, both national and international, might rank these goals differently, the following are important national security considerations:

1. Protecting the "warfighter" in the region (both military personnel and supporting civilians) against both natural and deliberate disease (*natural*: knowing and preventing/planning for endemic/enzootic diseases and *deliberate*: knowing and preventing/planning for potential weapons use by an adversary);

2. Protecting against transboundary threats such as emerging infectious disease and pandemics (for example, avian influenza and SARS);

3. Preventing and/or rapid reaction to major disease outbreaks that intensify human suffering and tax resources of communities/states; and

4. Preventing WMD (biological) proliferation, primarily addressed through safety and security measures to prevent the spread of hazardous biological agents, dual-use equipment, or dual-use expertise.

The backbone of initiatives to address biological threats can be termed "capacity building." Capacity building involves the imperative to improve surveillance, detection, reporting, and response capabilities. Capacity building constitutes a fundamental approach to biological threats, regardless of whether threats are of natural or deliberate origin. "The focus of capacity building should be on biological agents with zoonotic potential -- that is, agents that exist naturally in animal populations but that may accidentally infect humans as a dead-end host."[9] Examples of this would include avian influenza, anthrax, plague, tularemia, and presumably filoviruses. Therefore, surveillance and detection should be primarily focused on "high risk" animal populations.

To illustrate the relationship between natural and deliberate disease outbreak detection, let us consider the scenario in which an actor has perpetrated a biologically based attack. Detection must recognize the attack to limit its effects and to expedite treatment. Early intervention is critical. Biological threat expert Dr. Richard Pilch notes that in general an attack will be detected in one of two ways: a detection system alarm may be triggered or animal or human populations will begin to fall ill. "In the first instance, detection systems may identify an increased level of a biological agent over "background" levels that exist naturally in the environment, suggesting a deliberate biological event…"[10] The civilian BioWatch program, which is active in more than thirty U.S. cities, represents a critical tool in this kind of detection effort. In the second instance, characteristics of ill animal or human outbreaks may indicate a deliberate exposure. "Affected populations (both animal and human) may be identified by individual diagnosis and case reporting to public health agencies, sentinel surveillance in which representative subsets of a population are monitored for trends in such indicators of illness as over-the counter pharmaceutical sales and absenteeism…or syndromic surveillance in which subsets of a population are monitored for certain constellations of symptoms and signs associated with, for example, flulike, respiratory, gastrointestinal, cutaneous, or neurological illness."[11] This latter category requires sophisticated infrastructure and capabilities, to include laboratories and their personnel, communications systems, diagnostic capabilities, and social awareness. Surveillance systems do however, identify disease outbreaks with some sensitivity, and would apply to both natural and deliberate outbreaks. Hence, many of the same initiatives suggested by public health requirements of a country will facilitate the objectives of those interested in addressing the biological weapons threat.

THE U.S. BIOLOGICAL THREAT REDUCTION PGROGRAM[12]

The BTRP is one of five program areas within the U.S. Department of Defense's ongoing Cooperative Threat Reduction initiative, which for some 15 years has aided the states of the former Soviet Union in securing, safeguarding, and eliminating WMDs. BTRP seeks to preempt the diversion of dangerous biological agents, dual-use equipment, and/or technical expertise toward the development of an offensive biological weapons capability, whether state or sub-state in nature, by implementing robust biosafety and biosecurity measures, engaging scientists of the former offensive biological weapons program in peacefully-directed research projects with US or international collaborators, and eliminating infrastructure with potential dual-use applications when possible. BTRP also strives to establish improved local, regional, national, and international infectious disease surveillance in order to identify and address *any* outbreaks in the area of interest, whether of natural or deliberate origin. This last objective, known as threat agent detection and response (TADR), expands beyond traditional threat reduction and biodefense efforts to provide an improved public health capability that, when appropriately directed, may considerably reduce the burden of disease in the partner state. Therefore, while BTRP primarily addresses blowback from the collapse of the former Soviet Union with respect to the threat of biological weapons, TADR addresses not only the potential for deliberate outbreaks orchestrated by terrorists or states but also the potential for natural outbreaks of emerging and re-emerging diseases. The goal of this program is to achieve improved public health and veterinary health and thus address what is arguably the greatest concern in terms of worldwide impact, and impact upon *human security,* both at present and in the foreseeable future: natural disease.

Establishing TADR in former Soviet states, where the BTRP is currently focused, is critical to the assurance of national and international public health objectives in the coming years, *particularly given the proximity of these states to emerging and re-emerging disease outbreaks in China and Southeast Asia.* To meet these objectives, key challenges of "culture change" and sustainability must be addressed, and issues such as applicability to diseases of greatest public health concern, optimization of surveillance activities, and integration of public and veterinary health efforts must be carefully considered.

CHALLENGES

Challenge # 1: How can a public health "culture change" best be accomplished in countries in which prevailing practices are outdated and/or substandard?

Maxim # 2: Increasing capacity is a vital component of effective programs addressing both natural and deliberate outbreaks of disease.

Addressing and containing biological threats necessitates engagement with countries where outbreaks/incidents are likely to occur and where prevailing practices and infrastructure are often unsatisfactory. Training is a cornerstone of TADR capacity-building, and is arguably the most beneficial component of BTRP to the partner state. Dr. Pilch notes that "a trend had been observed among other international donors in former Soviet states in which equipment, supplies, and even new laboratories have been provided, but no training has been implemented to support these assets."[13] Predictably, the assets are under- or improperly utilized. He notes that "newer technologies such PCR and ELISA are notable in this regard.[14] For example, Azeri scientists had never utilized these technologies after they were provided by the Japanese government and the World Bank following the H5N1 influenza outbreak in 2006, and thus went unused until training was recently provided as a part of BTRP." [15] A belief in the effectiveness of such technologies is further required to ensure their continued utilization over time, and may be accomplished by such means as regular proficiency testing with results validated by international partner laboratories. Proficiency testing is also recommended to maintain competency of acquired skills, and regular refresher training is similarly recommended to ensure that new skills become ingrained in the individual and collective mindset of the public health practitioners and stakeholders.

Beyond training, alignment and integration with international public health bodies such as the WHO and CDC is strongly recommended, as these agencies offer both a model and "renewable resource" of best practices in public health that may guide or support efforts of the country in question.

Maxim #3: Capacity-building must be accompanied by commitment of authorities to truthful and timely reporting on disease.

Compounding the dangers imposed by substandard health infrastructures are government policies that sometimes employ dangerous delaying tactics, underplay the critical nature of a crisis, and distort facts concerning disease outbreaks. Even the best training cannot compensate for deficiencies in the political will of governments to require and encourage complete and timely reporting. Surveillance systems run on information, and information can be lacking not only because of deficiencies in the capacity to collect and evaluate, but also because of authorities who seek to distort or hide information that they feel might cause panic, require action to be taken against sectors of their economies, or cast their nations as incubators of deadly and dangerous diseases.[16]

Because of these deficiencies, but also because official diagnostic and health reporting can be slow and tedious, the IHR - 2005 explicitly acknowledge that non-state sources of information about disease will often pre-empt and precede official notifications. The reporting system now incorporates information sources other than official notifications; although the WHO notes that it will always seek official verification of such information. "This reflects a new reality in the world of instant communications: the concealment of disease outbreaks is no longer a viable option for governments."[17]

In place is the Global Outbreak Alert and Response Network (GOARN), which is comprised of a partnership to keep the international community constantly alert to the threats of outbreaks while providing an operational and coordination framework to access expertise and skill. Coordinated by WHO, the network is made up of more than 140 technical partners from more than 60 countries, of which the United States is one.[18]

Just as the GOARN system facilities early warning, the Global Public health Intelligence Network (GPHIN), launched in 1997 by the Health Canada, is a customized search engine that continuously scans websites in several languages for rumors and reports of suspicious disease events. Computerized text mining and human review classify and filter the more than 18,000 items flagged every day. Interestingly, 40-50% of the initial alerts on outbreaks investigated in the past 10 years by WHO have come from the mass media and other non-official sources.[19]

Challenge # 2: How can TADR and resultant public health benefits be ensured over time?

Sustainability is a key consideration throughout the implementation process, and plays a role in efforts involving all five aspects of TADR: personnel, procedures, tools, environment, and logistics. Of particular concern are sustainability personnel, tools, and environment requirements over time.

With respect to personnel, staffing shortfalls throughout public health systems, particularly in vulnerable countries, need to be addressed. Possible approaches currently suggested are reallocation of city-based staff to regions as necessary; cross-training of personnel; increased attempts to generate interest in the field among students and professionals, particularly through medical student rotations; coordinated training using international assets in

BTRP-engaged countries (Georgia, Kazakhstan, etc.) and in the United States, drawing upon student and professional pools to generate interest in infectious disease surveillance and response activities. Such programs might incorporate service commitments to ensure retention of participants upon completion, as incorporated, for example, in certain Fulbright scholarships.

With respect to tools, PCR and ELISA reagents are costly and require regular replenishment given their limited shelf-lives. Regular procurement of more standard consumables such as personal protective equipment and disposable laboratory supplies further contribute to this cost burden. Two approaches that have been utilized by the BTRP are procuring base equipment and supply packages from validated US and/or international vendors and procuring “pilot” quantities of equivalent equipment and supplies from local and/or regional vendors, and testing for compatibility and interoperability.

With respect to the environment, sustainability of both facility/infrastructure and supporting utility upgrades must be considered. Facility/infrastructure upgrades are performed utilizing locally or regionally available, fit-for-purpose materials whenever possible, such that cost-effective routine maintenance is readily achieved and spare/replacement parts are routinely available. Supporting utility upgrades poses a particular challenge in developing countries (such as Azerbaijan) where electricity, water, and sewer access is severely limited outside of the capital city of Baku. As a result, electrical generators sized to safely maintain essential facility operations are provided, as are wells and septic tanks. Importantly, electrical generators carry with them the additional requirement of fuel, often with considerable cost burden. For example, in most regions of Azerbaijan outside of Baku, power is only available from 8-9AM, 12-1PM, and 6-10PM. Careful financial planning is therefore often necessary to ensure that funds are available to meet fuel requirements over time.

Challenge # 3: Can the role of TADR be expanded to include infectious disease threats of primary public health concern?

The goal of TADR is to promote control of high priority pathogens as defined by the Department of Defense (DoD) and in accordance with its mission. In 2000, the Center for Disease Control’s (CDC) Strategic Planning Workgroup devised a list of three threat categories of critical biological agents. Threat categories were denoted as A, B, and C, with Category A agents deemed to pose the greatest threat to humans. The Workgroup took the following characteristics into account when classifying agents:

1. Public health impact based on illness and death;
2. Delivery potential to large populations based on stability of the agent, ability to mass produce and distribute a virulent agent, and potential for person-to-person transmission of the agent;

3. Public perception as related to public fear and potential civil disruption; and

4. Special public health preparedness needs based on stockpile requirements, enhanced surveillance or diagnostic needs.

The fact that these pathogens do not necessarily represent infectious disease agents of primary public health concern in a given state is well-recognized.[20] Furthermore, the priority pathogens list does not include a number of US Select Agents (identified as such due to potential consequences of their deliberate release). Coordination with a partner state and other US and international funding agencies has therefore been prioritized in order to ensure that diseases of concern are optimally addressed.

The recognition of the relationship between the mission of DoD and public health concerns about natural disease outbreaks is encouraging. For example, in Azerbaijan the WHO has funded surveillance of vaccine preventable diseases utilizing BTRP-provided assets. Assets developed through program requirements of TADR are invaluable in detecting disease outbreaks, regardless of whether these outbreaks are naturally occurring or deliberate.

Challenge # 4: How can surveillance and related reporting activities be optimized within TADR?

In order for a given case to be identified by TADR, the (usually sick) person or animal must be initially reported at the local level, i.e., it is a *passive* system. While useful in terms of outbreak management and interrupting disease transmission, this approach limits the ability of public and animal health professionals to identify background levels of disease in the population, monitor migration (and, with respect to influenza virus, reassortment) of pathogens, monitor trends with respect to environmental and host population factors, and, perhaps most importantly, implement targeted barriers in the earliest stages of, or even prior to, the initiation of an outbreak. *Active* surveillance must therefore be promoted and if possible implemented in deliberate fashion in target areas both of endemic/enzootic disease foci and of particularly high risk with respect to interspecies and zoonotic disease transmission -- for example, retail poultry and wildlife markets. Approaches to limit resource burden must be encouraged, for example cycling active surveillance efforts to correspond with the shelf-lives of reagents to ensure utilization prior to expiration and thus wastage.

It should be further noted that a single data source (in this case, the reporting of a sick animal or person in accordance with a particular case definition) is not optimal in terms of allowing the most timely, sensitive and specific warning of disease. Research suggests that monitoring additional data sources (e.g., over-the-counter pharmaceutical sales, child absenteeism) in conjunction with this primary data source may greatly enhance rapid and reliable event detection, particularly when spatially located as can and hopefully will be done with TADR (e.g., not simply locating cases to a particular region but rather to a specific district within the region and a specific locale—community/farm/etc.—within the district).[21] Given the challenges inherent to tracking such additional data sources in the former Soviet Union, however, DoD's mission may best be served by simply advising the partner state on how it might choose to complement the TADR system to this end in the future. Similarly, syndromic surveillance (looking for clusters of symptoms instead of possible diagnoses, potentially allowing earlier intervention and thus higher likelihood of successful mitigation) might also be discussed in this context.[22]

Alignment of the TADR reporting system to allow the sharing of real-time information among all regional and international stakeholders—including the Russian Federation and non-Russia former Soviet states, the European Union, and the US—is expected to be of immense benefit to all stakeholders, particularly when operated in coordination with the WHO Global Alert Outbreak and Response Network and surveillance efforts of the Food and Agriculture Organization (FAO) and the World Organization for Animal Health (OIE). Bridging potential gaps in the unified surveillance of and response to infectious diseases on a national and international level, in a sustainable way, is therefore a primary focus area of TADR implementation.

The "scope" of a disease outbreak must, of course, be estimated. This will include a consideration of factors such as "population susceptibility, infective dose, incubation period, modes of transmission, duration of illness, mortality rate, effectiveness of treatment interventions and population movement." [23]

On the domestic front, "BioSense," a Health and Human Services and Department of Homeland Security initiative, enables electronic transmission of health data to the CDC from national health data sources. These kinds of systems enable timely detection of natural outbreaks as well as potential deliberate outbreaks.

Challenge 5: How can information-sharing between public and animal health professionals be ensured?

Animal populations serve as effective sentinel populations for a number of infectious diseases including many caused by "especially dangerous pathogens" (EDPs) such that outbreaks in human populations are preceded by outbreaks among neighboring animal populations, which if appropriately acknowledged and addressed may prevent/limit zoonotic transmission or better prepare public health professionals to mitigate/manage impending human cases. Zoonotic refers to disease that can be transmitted from animals to people or, more specifically, a disease that normally exists in animals but that can infect humans. There are multitudes of zoonotic diseases, including Lyme disease, malaria, monkeypox, and West Nile.

Because human and animal surveillance activities proceed largely in parallel, such information-sharing requires procedural guidelines that optimize data exchange at regional and even local levels where human and animal activities are not yet linked. Integration of animal and human surveillance and response at all levels of operation is considered an essential component of TADR implementation—taking a lesson learned for example from US experience with the introduction of West Nile fever virus when lack of cohesion and communication among federal, state, and local public health and animal control departments and agencies allowed what had at first been a manageable event to spawn a national public health problem that persists to this day.

PART ONE: CONCLUSION

WHO is the international organization charged with promoting global public health and ensuring cooperation among nations to defend against health threats like pandemic influenza and the health consequences of conflict, natural disasters, and bioterrorism. Their most recent World Health Survey notes that "international public health security is both a collective aspiration and a mutual responsibility… (and that) the new watchwords are diplomacy, cooperation, transparency and preparedness." [24] In order to comply with the new IHR - 2005, nations will need to have in place effective systems for detection and control of public health risks by 2012.

Programs initiated by the United States, specifically the BTRP, are absolutely critical to assist nations to achieve these goals. Although initially intended as programs to prevent, detect, and intercept acts of bioterrorism, building capacity and networks of information sharing are vital components of the international public health initiative.

PART TWO: CASE STUDIES OF RECENT OUTBREAKS INVOLVING SUPERBUGS AND THEIR KIN[25]

> Since the 1970s, newly emerging diseases have been identified at the unprecedented rate of one or more per year. There are now nearly 40 diseases that were unknown a generation ago. In addition, during the last five years, WHO has verified more than 1100 epidemics worldwide.[26]

Among the 'epidemic prone diseases' are cholera, yellow fever, and epidemic meningococcal diseases, all of which are "resurgent" diseases. Severe Acute Respiratory Syndrome (SARS) and avian influenza in humans also pose serious threats. Ebola, Marburg haemorrhagic fever and Nipah virus require containment at their source due to their potential severity, requiring rapid detection and response. Although there have been many gains in controlling infectious diseases, the spread of antimicrobial resistance is of great concern. In particular, drug-resistant tuberculosis (XDR-TB) has appeared with more frequency.[27] Drug resistance is also apparent in diarrhoeal diseases, malaria, meningitis, and is emerging in HIV.

The increased use of antibiotics in both human health treatment and agriculture has prompted intense concern about "superbugs," that is, microbes that are immune to treatment. According to Dr. Roger Wetherbee, an infectious disease expert at New York University's Tisch Hospital, "(if) you take a capable microorganism…and you put it through the grueling test of being exposed to a broad spectrum of antibiotics…it will eventually defeat your efforts."[28]

Twenty well-understood diseases, including TB, malaria, and cholera, have re-emerged or spread geographically since 1973. Often, they have emerged in more deadly and drug-resistant forms. According to the CIA Report on Infectious Diseases, at least 30 previously unknown disease agents have been identified since 1973, including, HIV, Ebola, Nipah virus. No cures exist for these diseases.[29]

Many vector-borne diseases (*vector* is a term used broadly to refer to any animal that transmits human disease or plays an essential role in a parasite's life cycle) have emerged in new areas or re-emerged in areas where they were believed to have been eradicated. This has been a result of the lapse of control programs, as resources have decreased. With increasing urbanization, trade, and travel, some of these resurgent diseases have occurred in epidemic proportions. Witness, for example, dengue fever, which was responsible for a pandemic in 1998, with 1.2 million cases reported to WHO from 56 countries. The average annual number of dengue cases reported to WHO has nearly doubled in each of the last four decades.[30] In Mexico, cases of dengue are up 620% since 2001, and dengue has appeared for the first time in significant concentrations in regions of the United States.[31] Viruses, such as dengue, flourish where there are large amounts of standing water and in the unsanitary conditions that exist where there is uncontrolled urbanization.

Climate change may be having an effect on the spread of certain diseases into geographical areas that previously were less apt to harbor them.[32] Particularly mosquito-borne diseases such as malaria, yellow fever and dengue, are spreading into new areas. Warmer temperatures and increased rainfall have sent malaria into new areas of sub-Saharan Africa and Latin America. Incidences of water-borne diseases associated with warmer or temperature sensitive environments, such as cholera, also may increase.[33] Malaria is believed to be the vector-borne disease most sensitive to long-term climate change. Excessive rainfall and high humidity enhances mosquito breeding and survival. The seasonal duration of malaria may also increase in many currently endemic areas.

The displacements and hardships imposed by conflict also contribute significantly to incidences of disease. For example, from 1975-2002, during the civil war in Angola, Marburg haemorrhagic fever re-emerged as a major health issue. After the Rwanda genocide of 1994, hundreds of thousands of refugees fled to the Democratic Republic of the Congo. Close to 50,000 refugees died in an outbreak of cholera and dysentery, related to the contamination of the only available source of water and the lack of proper sanitation in the overcrowded camps.[34] During conflict, there is also less access generally to health care and proper nutrition, making at-risk populations more vulnerable to disease.[35]

To what extent should the changing pattern of disease in the world be considered particularly relevant to security calculations? Andrew Price-Smith has listed some questions that are important before framing an emergent or resurgent disease as a security threat:

1. Is the prevalence of a particular infectious disease rising within a given state's population and also worldwide?
2. Is this pathogen moving into new geographic regions or reclaiming lost territory, and is it affecting new demographics within given societies?
3. What regions (if any) are particularly vulnerable to this resurgence in infectious disease, and where are the greatest increases in prevalence taking place? and
4. At what rates are these pathogens expanding their territories, both demographic and geographic?[36]

THE CASE OF SARS [37]

> The short, sharp shock (of SARS) made us all stand up and pay attention…Governments were committed. Resources made available. People made aware. Health workers given tools for action. Information shared across borders. In short, there was global mobilization to fight a global threat.[38]

The outbreak of SARS in 2003 presented a prime illustration of the need for reporting networks, skill in detection and appraisal, and international cooperation. SARS was the first severe new disease of the 21st Century. It spread rapidly from human to human, required no vector, was not confined to a particular geographical region, incubated for more than a week, looked symptomatically like other diseases, (thus complicating diagnoses) and took a heavy toll of health workers (doctors, nurses, hospital staff). It had a high morbidity rate. It spread along international air travel routes, and understandably incited considerable panic.[39]

SARS emerged in 2002 in Guangdong Province, China. The first report, said to have affected 305 persons, causing 5 deaths, was received by WHO in February, 2002. A large percentage of those cases were reported to occur in health care workers. It took until April for China to permit a WHO team to visit the province. Meanwhile, SARS was transported out of China by an infected doctor to a 4 star hotel in Hong Kong. The infamous ninth floor of that hotel proved deadly to guests and visitors there, and the disease quickly spread to Hong Kong, Vietnam, and Singapore. Some guests flew home to Toronto and elsewhere, and the new disease showed up in Hanoi, Hong Kong, Singapore, and Toronto -- the initial "hot zones."

Because staff didn't know that this was a new disease, they did not properly employ "barrier protection."

In an unprecedented move, the WHO quickly issued emergency travel advisories and a worldwide alert, to raise consciousness about the disease. Through prompt diagnosis, immediate isolation, infection control, and contact tracing, the number of additional disease cases was kept low. The cumulative total number of cases surpassed 5000 in April 2002, and 7000 on 8 May, when cases were reported from more than 30 countries, all over the world.[40] Public panic was widespread, creating pressure on hospitals and health care works. In Singapore, military forces were deployed to assist in contact tracing and to enforce quarantines.

SARS had no vaccine and no treatment, requiring health workers to resort to isolation and quarantine. The virus frequently mutates, and the initial symptoms are common and non-specific. Patients can easily slip through diagnostic safety nets, and infect others. The incubation rate of 10 days means that air travel can take place before someone displays its typical pneumonia-like symptoms. Fatality was in the range of 14 – 15 %, but much higher in more elderly populations.

The customized search engine called GPHIN was extremely useful in gathering epidemic intelligence. GOARN was also a mechanism that linked together in real time, many existing networks to keep the international community alert to outbreaks.

WHO identifies the most important lessons of the SARS outbreak as:

1. The importance of preparedness, and the necessity to rapidly create a high-level of awareness so that cases will be quickly detected and isolated;
2. The firm need for the new IHR, and the need for strong international collaboration to work on diagnoses and protocols, and
3. The need for transparency and surge capacity.

Most diseases present huge problems with surge capabilities, often because health care personnel are themselves at risk. The "worried well" also become a factor, as a consequence of panic, widespread misunderstanding of protocols and diseases, and misinformation.[41] Cases during the early phase of the SARS outbreak were not openly reported by China. In clear contrast, was the response at the highest levels of government of Vietnam, who displayed commendable commitment to reporting and collaboration. The contrast between the policies of Canada and Singapore in dealing with SARS is also stark, and presents important lessons about public information, awareness, and cooperation in quarantine situations.

TUBERCULOSIS, MULTI-DRUG RESISTANT TB, AND EXTENSIVELY DRUG-RESISTANT TB

WHO declared TB a global emergency in 1993, and the multidrug resistant TB is particularly dangerous. Multi-Drug Resistant TB is defined as TB that is resistant to the two leading first-line TB drugs. Prevalent in Russia, India, Southeast Asia, Sub-Saharan Africa and parts of Latin America, TB continues to kill hundreds of thousands of human beings every year. Up to 50% of people with multidrug resistant TB will die of their infection in spite of treatment. Tuberculosis that is extremely highly resistant to treatment by drugs is called XDR-TB; XDR-TB is resistant to, in addition to the two leading first-line drugs, any fluroquinolone and at least one second-line injectable drug. The increase in TB incidence is severely complicated by co-infection with HIV.[42] The TB bacillus is latent in close to one third of the world's population, and is activated in people with compromised immune systems.

Drug resistant tuberculosis has developed largely because patients with tuberculosis have been left unsupervised to continue faithfully on prescribed therapeutic drug regimens. When the patient does not complete the protocols as prescribed, or does not have proper access to the necessary drugs, resistance can develop.[43]

In the United States, 49 cases of multi-drug resistant TB have been identified between 1993 and 2006.[44] There are now immigration requirements to try to detect TB in those coming into the United States. The most important initiatives, however, are being taken to prevent XDR-TB in HIV/AIDs patients, as the compromised immune systems of these persons make them particularly vulnerable. A February 2008 WHO report noted the highest levels ever of XDR-TB in the world, and its presence in 45 countries. About 5% of all TB cases are XDR-TB, involving about 450,000 persons. The highest rate is in Baku, Azerbaijan, where 22% of the new TB cases are XDR-TB.[45]

AVIAN INFLUENZA[46]

> It is tempting to believe that an avian influenza pandemic will never happen, but an understanding of the influenza virus and the history of its deadly impact on global populations through the ages makes the threat too serious to ignore. While one cannot say when it may become a reality, it is clearly an ever-present danger."[47]

Avian influenza is an infectious disease of birds caused by type A strains of the influenza virus. An extensive reservoir of influenza viruses perpetually circulates in wild waterfowl populations. Not all virus strains of the H5 and H7 subtypes are highly pathogenic, but most are believed to have the potential to become so.[48] After circulation for short periods in a poultry population, these mutate into highly pathogenic viruses. Most experts believe that wild waterfowl introduce the viruses, in their low pathogenic form, to poultry flocks, although this may have changed recently. Infection of backyard poultry flocks are difficult to control, and are associated with human exposure and infection. Sometimes households will consume poultry that are sick, and therefore risk exposure during the process of food preparation.

The H5N1 virus was first recognized in chickens in Scotland in 1959, and later began to emerge in poultry flocks in Southeast Asia, at first causing only mild symptoms of disease in the fowl until the 1990s. In late 1996, the virus had mutated to a highly virulent form that could kill chickens within two days with a nearly 100% mortality rate. In 1997 the first human cases of highly lethal H5N1 influenza occurred in Hong Kong, after which there was a massive culling of poultry. In 2003 the virus reemerged in a Hong Kong family, who had visited mainland China.[49]

The most severe outbreaks of avian influenza among poultry occurred in 78 South-East Asian countries, beginning in mid-2003. The pathogen, the H5N1 strain of Influenza virus A, is now endemic in domestic birds in much of Asia. In 2005, the geographical distribution of the virus in birds expanded far beyond Asia. Reports of the disease in birds came in from Russia, Kazakhstan, Turkey, Romania, and Ukraine. Croatia and Mongolia reported the virus in wild birds. During 2005, the fears about changes in the virus have been compounded by finding a highly pathogenic strain of the virus in migratory birds, suggesting that the virus may have mutated and bounced back into the wild bird population. This change can probably be traced to Central China. Deaths of wild birds have increasingly been reported along migratory routes.

In 2006, the virus in birds expanded again, into Africa, Asia, Europe, and the Middle East. The virus then spread to poultry in many highly populated and poor areas, compounding problems of detection and reporting. The fact that this highly pathogenic virus is now endemic in wild birds and poultry in some of the most impoverished parts of the worlds, is very worrisome – for an outbreak among humans is least likely to be noticed by either the media (much reporting comes from electronic scanning of media reports) or health authorities. Changes in the transmission of the virus might go long unnoticed and unheeded, due to lack of media coverage, poor infrastructure including paucity of laboratories and skilled health workers, and lack of health services available to the poor.

Although there have been relatively few human deaths from avian influenza to date, the distribution of the virus in avian populations is substantial, and the economic consequences of the disease have already been huge. The Asian poultry industry has sustained substantial losses, and the distress caused by these losses is enormous in economies dependent on the agricultural and food producing sectors.

Re-emphasizing one of the points made in Part One of this paper, that there is a strong connection between the animal and the human world in the spread of natural disease outbreaks, one approach is to decrease the risk of the spread of disease by decreasing contact among species. “Closing down retail poultry markets in Hong Kong for one day per month reduced the rate of the H9N2 avian influenza virus in market birds.”[50] Quails have been identified as very important carriers of the virus – ones that often are infected and can transmit the virus through the respiratory tract, whereas other fowl transmit through feces. Therefore, quail are considered critical players in the avian influenza equation. In Hong Kong, quail have been banned from poultry markets, and ducks and geese are sold chilled. The abolition of live bird markets would greatly assist attempts to limit the spread of the virus; however, cultural practices are very hard to change.

The first human cases occurred in 2003 in Vietnam. By April 2006, close to 200 laboratory confirmed cases had been reported in people in Azerbaijan, Cambodia, China, Djibouti, Egypt, Indonesia, Iraq, Thailand and Turkey. In the critical region bridging Asia and Europe, nine deaths were reported as of May 2006 in Azerbaijan and Turkey. In humans, death results from infection more than 50% of the time.[51]

The critical change in terms of a potential pandemic would be that of confirmed and sustained human to human transmission of the H5N1 virus. Investigating this has been difficult. Most human cases so far have involved the transmission of the disease from infected birds, especially domestic poultry, to humans. When several members of a single family have contracted avian influenza, members of that family have invariably been exposed to the same source of infection as well as to one another. Investigations of disease incidents suggest that transmission requires “very close contact with an ill person.”[52] By May 2007, 12 countries had reported 308 human cases including 186 deaths.[53]

Two principal mechanisms can be used by a virus to improve its transmissibility among humans. The first is “reassortment, in which “genetic material is exchanged between human and avian viruses during co-infection of a human or pig. Reassortment could result in a fully transmissible pandemic virus, announced by a sudden surge of cases with explosive spread.”[54] The second mechanism is more incremental, in which adaptive mutation enables the virus to bind to human cells, through successive infections of human beings. “Adaptive mutation, expressed initially as small clusters of human cases with some evidence of human-to-human transmission, would probably give the world some time to take defensive action, if detected sufficiently early."[55]

"A prototypic example of the constant struggle between microbes and man is the evolutionary success of influenza viruses as they adapt to their many hosts, including humans."[56] The threat of a pandemic from H5N1 is still viable. Based on experiences involving the 1918 influenza pandemic, that killed more than 50 million people in 18 months (when the global population was 2 billion), WHO estimates that a severe avian influenza pandemic could kill 25% of the world's population, more than 1.5 billion people. Even in a mild form, the social and economic disruption would be without precedent.[57] Avian influenza would be more contagious than SARS, spread by coughing and sneezing and with an incubation period too short to allow for adequate contact tracing and isolation. Therefore, many interventions have been taken to control initial outbreaks in poultry, including the culling of millions of birds.

WHO has tried to be extremely pro-active concerning a potential avian influenza pandemic. It has distributed field investigation kits and trained investigators. The GOARN mechanism has been mobilized for prompt reporting. Strengthening the early warning system is critical, as is intensifying rapid containment operations to reduce human exposure to the H5N1 virus.

Cumulative Cases and Deaths Attributed to H5N1 since 2003[58]

Country	2003		2004		2005		2006		2007		2008		Total	
	cases	deaths	cases	deaths	cases	deaths	cases	deaths	cases	deaths	cases	deaths	cases	deaths
Azerbaijan	0	0	0	0	0	0	8	5	0	0	0	0	8	5
Bangladesh	0	0	0	0	0	0	0	0	0	0	1	0	1	0
Cambodia	0	0	0	0	4	4	2	2	1	1	0	0	7	7
China	1	1	0	0	8	5	13	8	5	3	3	3	30	20
Djibouti	0	0	0	0	0	0	1	0	0	0	0	0	1	0
Egypt	0	0	0	0	0	0	18	10	25	9	7	3	50	22
Indonesia	0	0	0	0	20	13	55	45	42	37	20	17	137	112
Iraq	0	0	0	0	0	0	3	2	0	0	0	0	3	2
Lao People's Democratic Republic	0	0	0	0	0	0	0	0	2	2	0	0	2	2
Myanmar	0	0	0	0	0	0	0	0	1	0	0	0	1	0
Nigeria	0	0	0	0	0	0	0	0	1	1	0	0	1	1
Pakistan	0	0	0	0	0	0	0	0	3	1	0	0	3	1
Thailand	0	0	17	12	5	2	3	3	0	0	0	0	25	17
Turkey	0	0	0	0	0	0	12	4	0	0	0	0	12	4

Vietnam	3	3	29	20	61	19	0	0	8	5	5	5	106	52
Total	4	4	46	32	98	43	115	79	88	59	36	28	387	245

Total number of cases includes number of deaths.
WHO reports only laboratory-confirmed cases.
All dates refer to onset of illness.

The international community requires time to adjust and store vaccines appropriate to the ever-mutating avian influenza virus. For this reason, public health surveillance is critical. Just as critical are guidelines that assist communities in dealing with natural disease outbreaks. WHO has developed detailed protocols and "best practices" in the effective handling of disease outbreaks.[59] From the first indication of sustained human to human transmission, it would take approximately six months for a vaccine to be developed. Then questions (all of which involve ethical, political and strategic calculations) arise about how much vaccine can be made, how and where it should be stockpiled, and to whom it would be allocated (a question addressed in a fascinating way in the Grosselin portion of this paper.) Other important questions will arise if the H5N1 virus mutates to permit sustained human to human transmission: should the military be mobilized for quarantine? When do you call for quarantines? Can you convince your population to shelter in place? Ultimately, questions about how the health community and authorities will respond become incredibly important. Will doctors and nurses stay the course in the face of incredible risk?

What about antivirals? Some of these are excellent, but resistance may develop almost immediately. However, amantadine and rimantadine and neuraminidase inhibitors will provide the front line of battle against avian flu should a pandemic arise. Once again, the question of how to stockpile, where to stockpile, and how to allocate these assets will be ethical and strategic questions of major proportions, if the world is confronted with pandemic influenza.

PART TWO: CONCLUSION

Health concerns now constitute a critical portion of the "human security" debate. Globalization has helped confront disease, through information sharing and coordination of international efforts. However, it has also enabled rapid spread of lethal diseases that may arrive on a nation's territory through infected persons, vectors, or deliberate release of pathogens. Climate change and resistance to anti-microbial drugs are changing global disease patterns, and in some cases diseases that were once considered contained are re-emerging with increased virulence and wider geographic distribution. Avian influenza presents a huge potential health challenge that, if it should occur, would present a catastrophe of unimaginable proportions.

Experts in health fields still contend that a global pandemic of influenza or something similar is a question of “when, and not if.”

Increased capacity, infrastructure, surveillance, detection, and information sharing, to include recommended plans of action should outbreaks occur are essential features of the coordinated attempt of the international community to address the changing global health picture and the dangers of a potential pandemic. Programs put in place to address the biological weapons threat, such as the U.S. initiative, the BTRP, has served a critical dual purpose. As it seeks to prevent the spread and use of biological weapons, the program also serves to strengthen health infrastructures, diagnostic capability, networks of communication and information sharing, and availability of health services in underserved regions – all of which are critical in containing natural outbreaks of disease. Although the reach of BTRP is limited to certain host countries, many of the experiences gained in the implementation of BTRP are vital sources of guidance for future health initiatives of all kinds that will ultimately have a critical impact on global health security.

MODELING INFLUENZA BASED ON COMPARTMENTAL ACCSS TO MEDICAL FACILITIES

In the event that H5N1 were to mutate into a pandemic within the human population, military commanders of U.S. installations on foreign soil would face the challenge of continuing to carry out their mission while limiting the effects of the pandemic on their troop population and the host nation community. For many of these installations, a gap will exist between the medical capabilities of the U.S. installation and the host community. In the absence of a vaccination, this gap would consist mostly of access to antiviral drugs and treatments (AV).

Absent a vaccination, an antiviral treatment is the best way to reduce the spread of influenza. Such drugs as Oseltamivir and Zanamivir can reduce the duration and severity of influenza [4]. In the event of an emergent strand of influenza, antiviral drugs would serve as a substitute for a vaccination for the beginning of the spread while a vaccination was researched and produced. For the model, we will look at the effects of extending AV coverage to host nation communities at the expense of the resources available to the military installation. In particular, two separate strategies will be studied. One strategy, defined as “greedy” sees the U.S. installation hording their AV treatment availability for only those individuals under the span of control of the installation. The “cooperative” strategy sees the installation extending AV coverage into the host community.

In “Modeling the Worldwide Spread of Pandemic Influenza: Baseline Case and Containment Interventions” [1] a stochastic model was used to simulate the global spread of pandemic influenza, taking into account airline traffic between major world cities. This simulation was than used to test different AV distribution strategies. Based on this model, the study concluded that a "cooperative" strategy where countries with large stockpiles of AV treatments redistributed them globally was more effective in containing the disease than a "greedy" strategy [1]. The contrast in AV availability in this study is similar to that which exists between some U.S. installations and their host nation communities. Thus, the model used in Colizza et al. was modified to reflect the dynamics of a pandemic in a U.S. installation.

MODEL

A deterministic model was developed to simulate these situations. This model assumed that the military base could carry out its missions while maintaining a closed population (a logistical hub such as Ramstein Air Force Base would not satisfy this assumption, since cargo and personnel go into and out of the airbase every day). In addition, it was assumed that the base relied on a group of host nation contractors and military personnel to successfully carry out its mission. Every member of the population existed in one of twelve compartments, six compartments for personnel that fell under the installations medical facilities, and six compartments for foreign contractors and other host nation members of the community. For example, the compartment $S_m(t)$ described the military population susceptible to the disease at time *t*, with time measured in days. The compartment $S_h(t)$ represented the same category within the host nation population. All compartments are given in Table 1.

$S_m(t)$ $S_h(t)$	Susceptible – Have not acquired immunity
$L_m(t)$ $L_h(t)$	Latent – Exposed to, but not actively shedding the virus
$I_{ma}(t)$ $L_{ha}(t)$	Infected Asymptomatic – Infected without symptoms, shedding the virus
$I_{ms}(t)$ $I_{hs}(t)$	Infected Symptomatic – Infected with symptoms
$I_{mt}(t)$ $I_{ht}(t)$	Infected with AV Treatment – Infected but obtaining AV treatment
$R_m(t)$ $R_h(t)$	Removed – All that have had the disease run its course, including those with acquired immunity or death

Table 1. Model Compartments

Members of the population can exist in only one compartment and must do so within the following progression: a "susceptible" individual becomes a "latent" carrier of the disease after an interaction with one of the three "infected" compartments. After the incubation period has elapsed, an individual becomes actively "infected", and is either symptomatic or asymptomatic, which determines an individual's infectiveness. If an individual is infected with the disease and displaying symptoms, the symptoms can be identified and the member can receive AV treatment. Regardless, after a fixed period of time, the disease runs its course and the infected member enters the "removed" compartment.

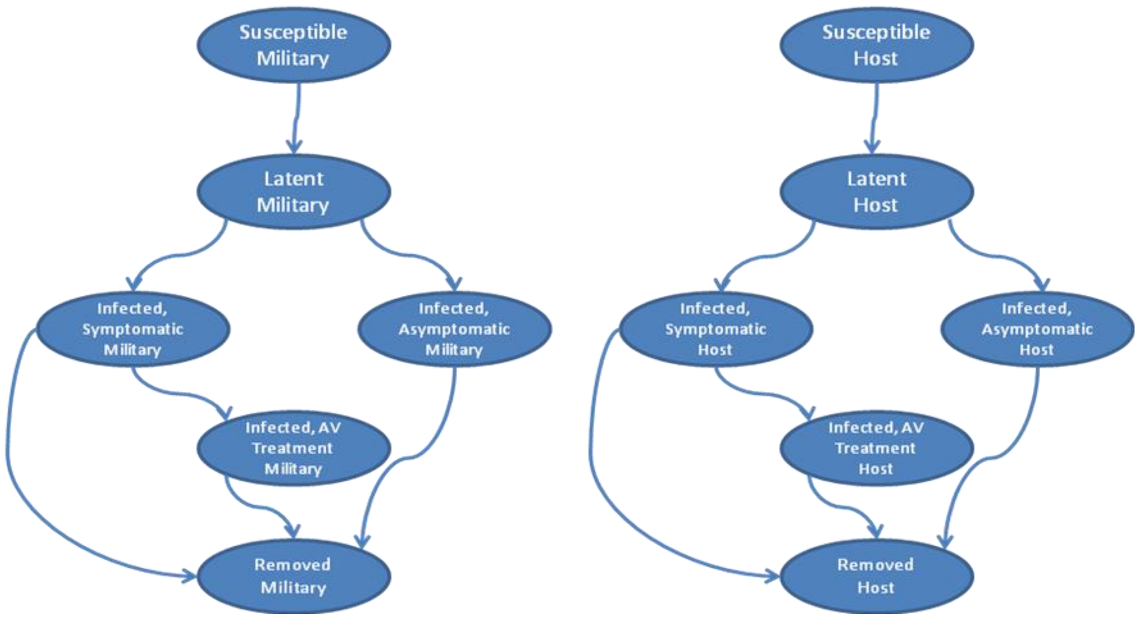


Figure 1. The Compartments within the utilized model. Individuals can only exist in one of the 12 compartments with arrows indicating the possible transitions that could exist.

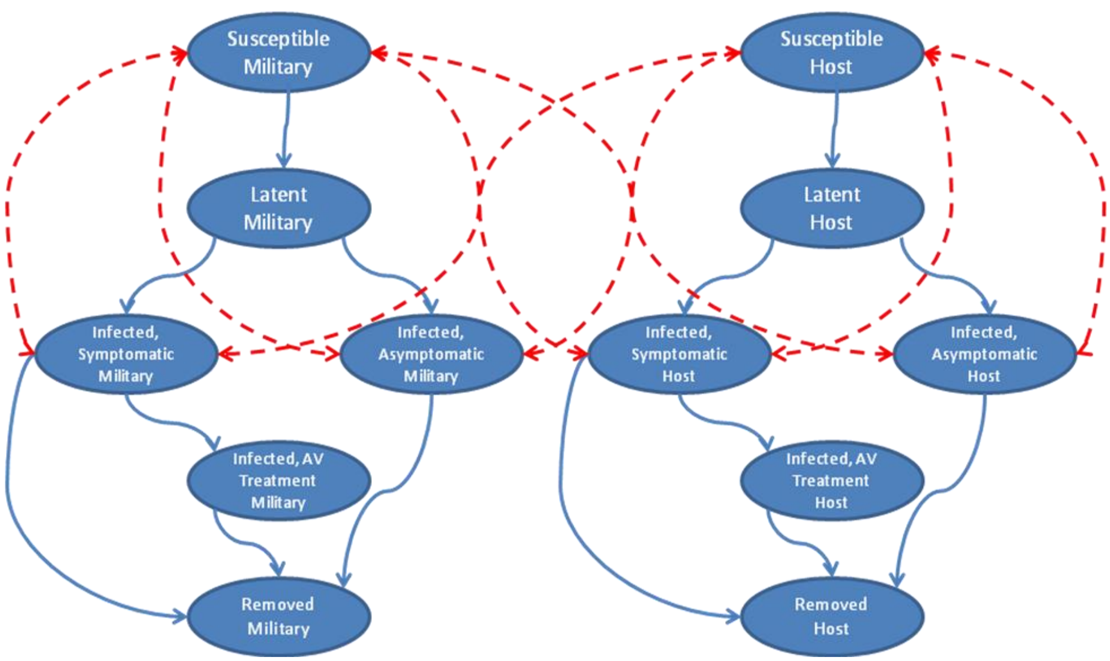


Figure 2. In this figure, dashed arrows indicate an interaction that must take place before a member can move from the "Susceptible" compartment to the "Latent" compartment.

A set of parameters determines the rate of time that an individual spends in each compartment. The parameter β represents the transmission rate constant, which quantifies the probability per unit of time that an interaction will result in the "successful" transmission of the disease. The higher this number, the more likely an interaction between susceptible and infected individuals will result in the transmission of the disease. This value depends on the probability of interaction and how contagious the infected individual is. If an individual is receiving AV treatment or is asymptomatic, they are assumed to not be as infectious, and hence β is scaled down. The mean incubation period (ε^{-1}) and the mean duration of infection (μ^{-1}) determine how long an individual remains in the "latent" and the "infected" compartments, respectively. The mean duration of infection is decreased if an individual receives AV treatment.

The most important constant that describes the model is the basic reproductive ratio, R_0. This ratio can be viewed as the number of first generation transmissions that occur, on average, from a single individual being introduced into a virgin population (no immunity within the population). Because AV drugs reduce the transmission constant, they reduce R_0. Thus it is possible that the same disease has a different R_0 within the military community and the host nation community. If $R_0 < 1$, then the disease will die off, since in each generation, the disease will infect less than the number of people who are currently infected. If $R_0 = 1$, the number of infected individuals stays constant, and if $R_0 > 1$, the disease will run its course as a pandemic through the population.

Incorporating AV Treatment into the Model

To model AV coverage, it was assumed that a certain probability existed that a symptomatic individual would be detected and AV Treatment initiated. In a "cooperative" strategy, this probability was decreased for members of the installation at the expense of increasing the same probability in the host nation community. This reflects a certain percentage of resources from the installation being used to help mitigate the spread of the disease within the host community.

The parameters needed to run the model were obtained from the research conducted in Colizza et. al [1]. The main parameter that was varied was the basic reproductive ratio (R_0, which was numerically estimated with respect to the entire population, and not either community). Three separate R_0 values were considered: $R_0 = 1.1$, $R_0 = 1.5$ and $R_0 = 2.0$. For each R_0 value, three test cases were run: a baseline (no AV coverage), a "greedy" strategy (the DoD installation uses all its resources for itself) and a "cooperative" strategy (the DoD installation shares it resources with the host community, even though it doesn't have enough to cover the entire community population). All scenarios were run in conditions to simulate those that surround Incirlik Air Base, Turkey. The installation population of Incirlik Air base is around 2,500 with 900 host nation contractors working on base that live in the host community [3]. The area around the host nation community has a population around 15,000. The classical RK4 numerical solution was used to carry out the scenarios.

DISCUSSION OF RESULTS

The table below gives the results of these simulations. The parameters that produced the given reproductive values were calculated for the baseline scenario and then used within the "greedy" and "cooperative" strategy.

Baseline			
	Max Day	Max Infected	Max Symp
R = 1.1	33	690	455
R = 1.5	13	1125	742
R = 2.0	9	1213	800
Greedy			
	Max Day	Max Infected	Max Symp
R = 1.1	36	292	110
R = 1.5	13	643	291
R = 2.0	9	738	356
Cooperative			
	Max Day	Max Infected	Max Symp
R = 1.1	42	339	162
R = 1.5	15	800	431
R = 2.0	11	897	500

Table 2. Model Results, Days, People Infected, People Symptomatically Infected

Because the goal is to make a policy recommendation to the military commander, these results look at just the compartments attached to the military installation, and not the host nation community.

As the basic reproductive number increases, the severity of the disease increases. This manifests itself in both how much time passes before the peak day occurs, as well as the peak values for the pandemic. Looking at the baseline, an influenza pandemic with a basic reproductive number of 1.1, the disease reaches its peak after nearly five weeks. If the disease's basic reproductive number is increased to 1.5, the pandemic reaches its peak within the military community after only two weeks. The number of infected at the peak also increases from 690 to

1125 people. For values over R_0 = 2.0, the disease spread so quickly that the results were trivial.

From the “baseline” scenario to the “greedy” scenario the results are fairly intuitive. With the introduction of AV coverage, the spread is delayed within the military community and the number of infected (both symptomatic and total) drastically decreases. Because it is assumed that the vast majority of fatal cases come from those with cases of symptomatic infections that go untreated, reducing the “Max Symptomatic” number also reduces the death rate. The “greedy” AV treatment strategy has the result of decreasing the spread and severity of the spread of the disease. For R_0 = 1.1, the disease eventually dies off before running it course through the entire population (Appendix I).

The “cooperative” strategy scenario supplies interesting conclusions with regards to policy recommendations. For R_0 = 1.5 and R_0 = 2.0, the “cooperative” strategy increases the speed and severity of the disease within the military community. From the viewpoint of a military commander trying to minimize damages of an outbreak of the disease, it would make little sense to divert installation facilities to the host nation community. While such a strategy would greatly decrease the severity of the disease within the host community, it does so at the expense of American lives and mission readiness.

For R_0 = 1.1, however, the results are drastically different and suggest a different strategy. The disease is actually delayed while the peak infected numbers rise only slightly. The reason this happens is that for such a small basic reproductive number, the portion of AV coverage introduced into the host community was enough to eventually force the disease to die off before running through the entire susceptible population. This delay may also provide time for the disease to be combated more efficiently and slow down the spread even more. Hence, for diseases that are less infectious, a “cooperative” strategy results in the optimal policy for both the host nation and the military community.

These results align with the work conducted in Colizza et al. Across the entire population, the spread of the disease is slowed down and the peak number of infections decreases. From a global perspective, a “cooperative” strategy decreases the spread of the disease when compared to a “greedy” strategy. Unfortunately, this is not all a commander has to take into consideration. The military commander must mitigate damages done to the installation population to minimize damages done to mission readiness. In a small population, the AV coverage does not cause the equilibrium mark to stabilize quickly enough for high basic reproductive constants. If the commander’s goal was solely focused on limiting the spread of the disease across the entire population, including the host nation population, then a "cooperative" strategy would make sense. However, taking into account the mission requirements, a "cooperative" strategy can only be recommended for situations were the basic reproductive number is very close to one.

It is hard to get a solid estimate of the basic reproductive number as a disease is emerging. In addition, for the same strand, the basic reproductive number could vary across communities based on other conditions, such as sanitation and natural susceptibility. It would be extremely difficult to give the commander a concrete value of the basic reproductive constant, making the decision boundaries even more difficult to decipher.

FUTURE RESEARCH

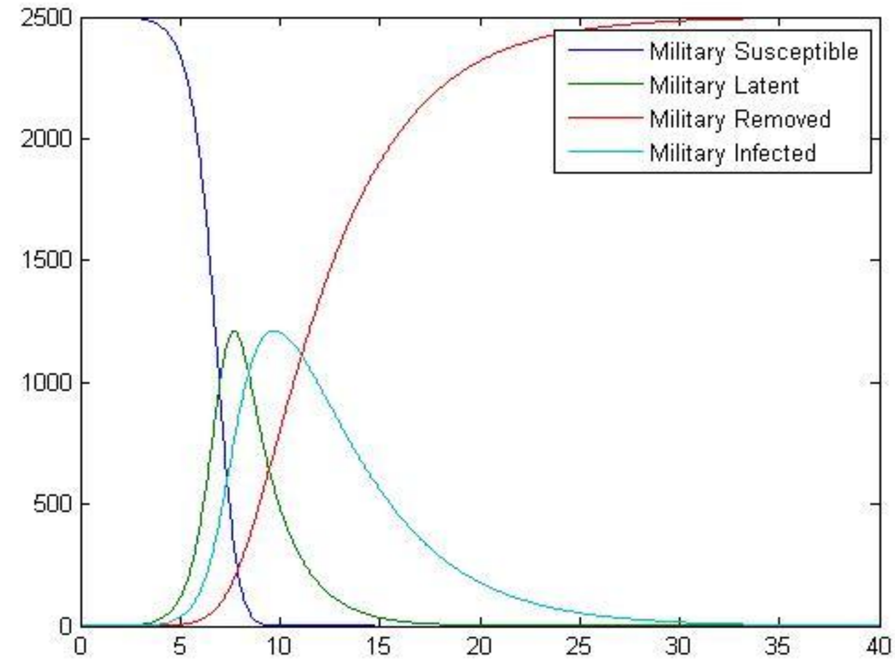
The model that was used was strictly deterministic. In a real world situation, the incubation period, infection duration, transmission rate, and other parameters are not the same for all cases. Each parameter has an associated distribution. Implementing this idea would change the model from a deterministic model to a stochastic model. In addition, if the disease does not occur for the first time within the military community, there would likely be some warning before the disease hits. This could increase the detection rate early during the spread. In addition, when there are not a lot of individuals infected, some of the installation resources could be diverted to the host nation community without adversely affecting the military community. Finally, the specific military mission could be incorporated to provide a more accurate model. In this model, it was assumed that the military mission required the host nation contractors to come on base everyday. This may not be in the case. In addition, a logistics base could not be modeled as a closed population.

CONCLUSION

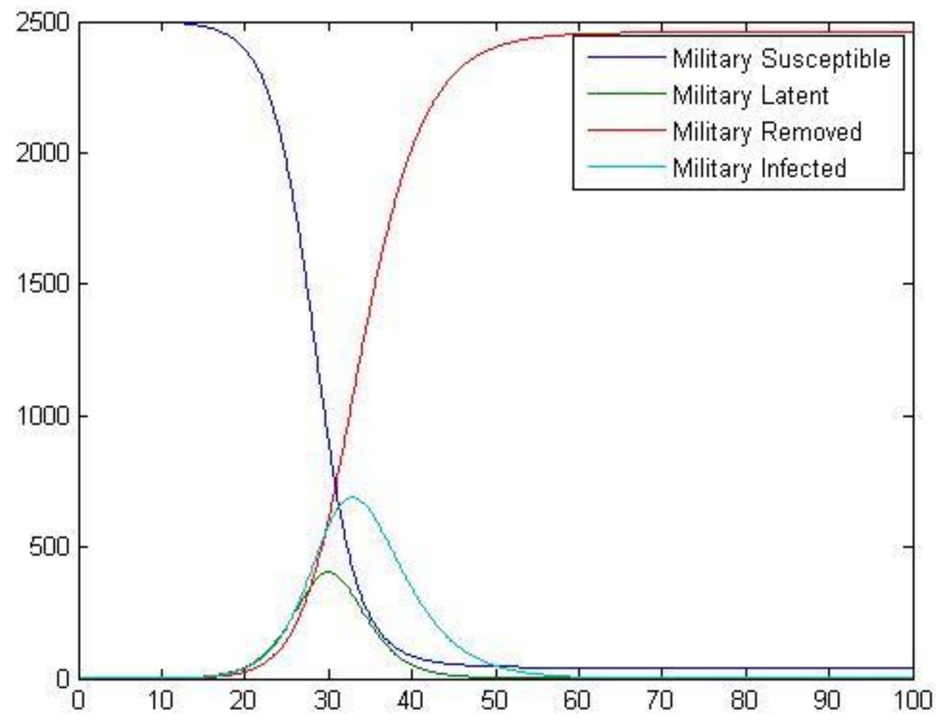
The dynamics of an influenza pandemic in a population greatly segmented in medical resources was examined through a deterministic model. Such a model was then applied to a military community. Antiviral treatment coverage was introduced as part of the model, with infected individuals experiencing a shortened duration of infections and not being as contagious. Three different scenarios were looked at: a "baseline," "greedy," and "cooperative" strategy. While previous studies demonstrate that, on a global scale, a "cooperative" strategy decreases the severity of the disease for the entire population; this was not the ideal strategy for a military installation unless the basic reproductive value was very close to one. Thus, based on the current model, it is recommended that military commanders only enact a "cooperative" strategy for less severe outbreaks and not all situations.

APPENDIX

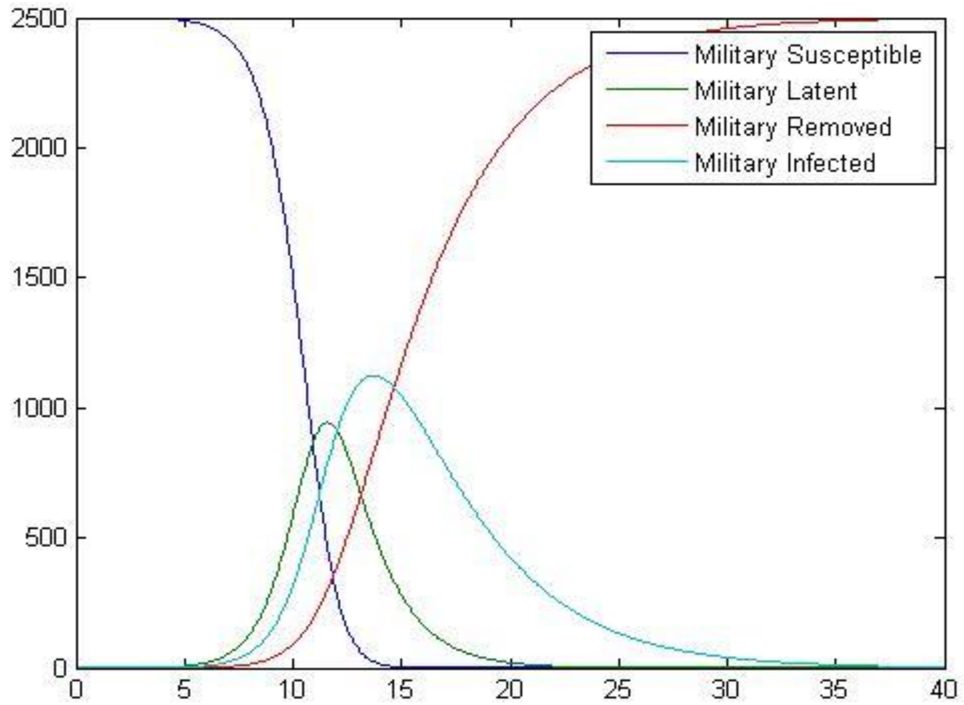
Baseline: People versus Time (Days) $\mathbf{R}_0$ = 1.1



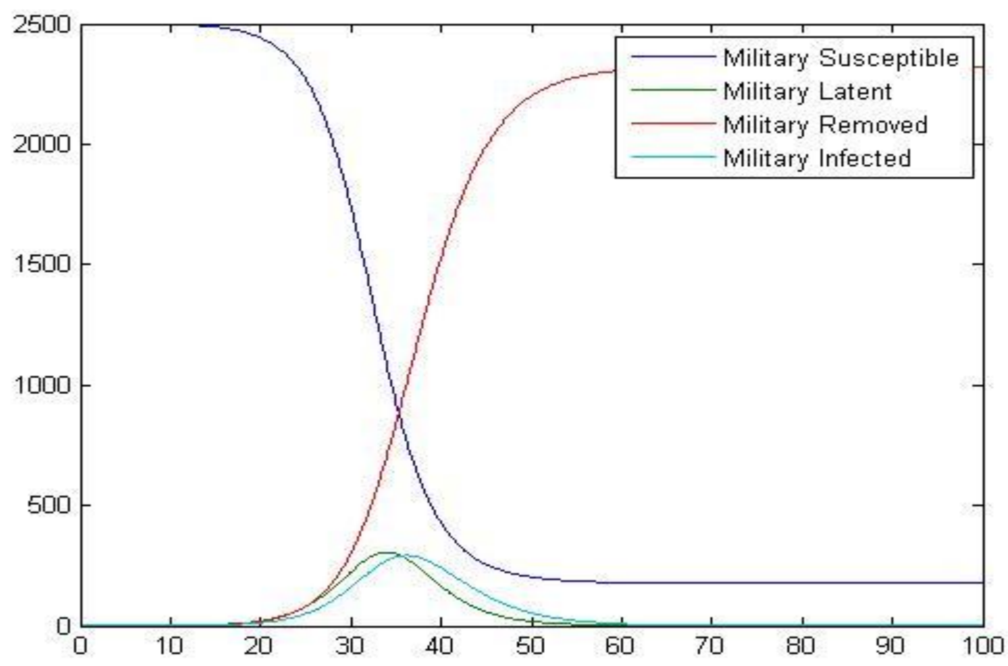
Baseline: People versus Time (Days) $\mathbf{R}_0$ = 1.5



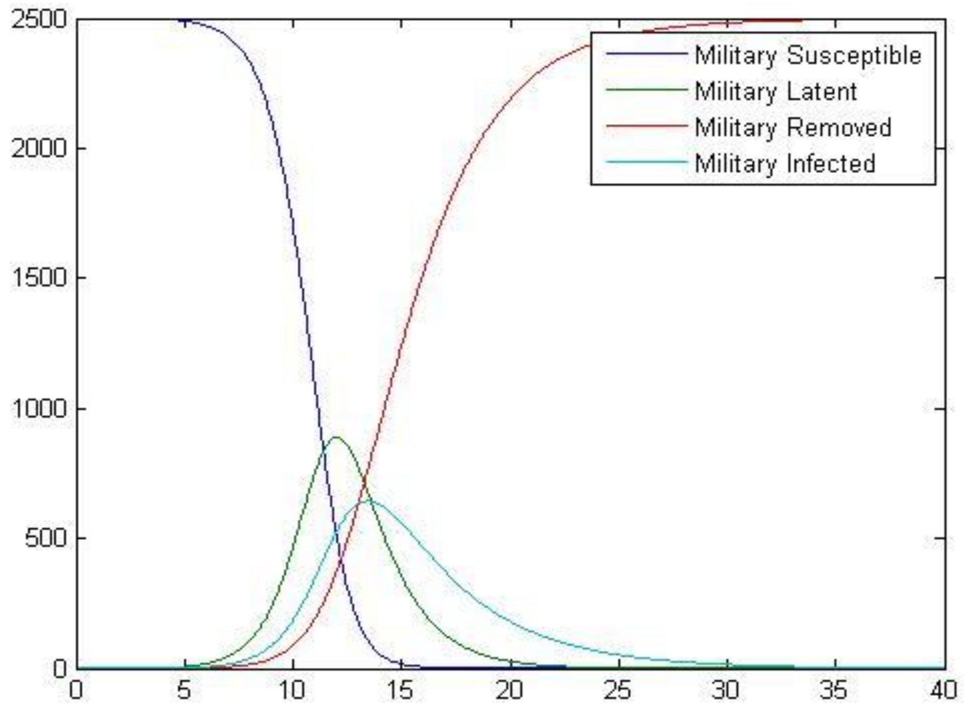
Baseline: People versus Time (Days) R_0 = 2.0



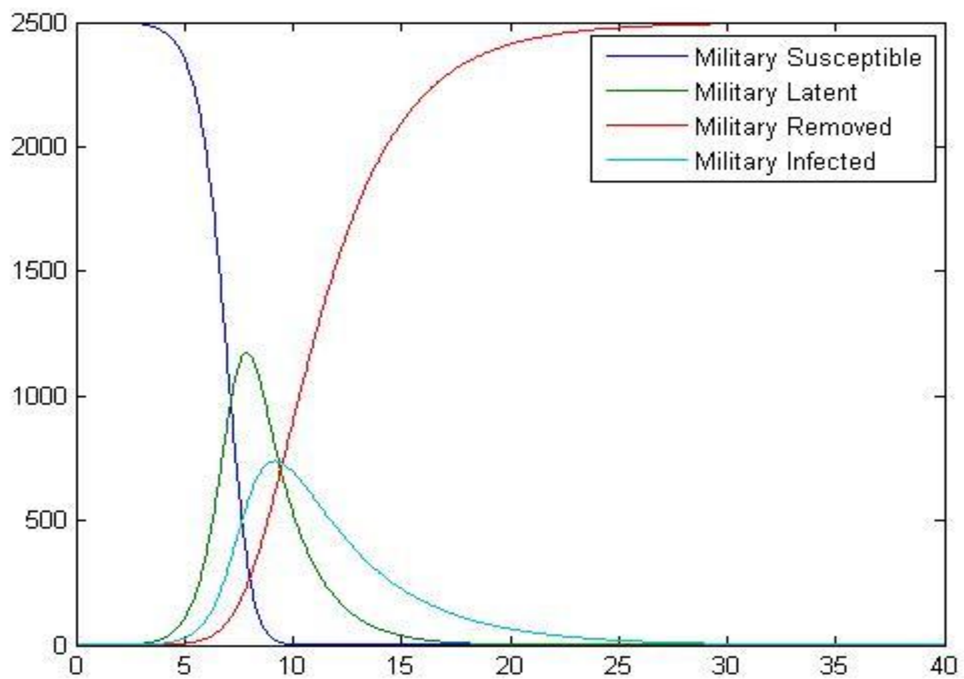
Greedy: People versus Time (Days) R_0 = 1.1



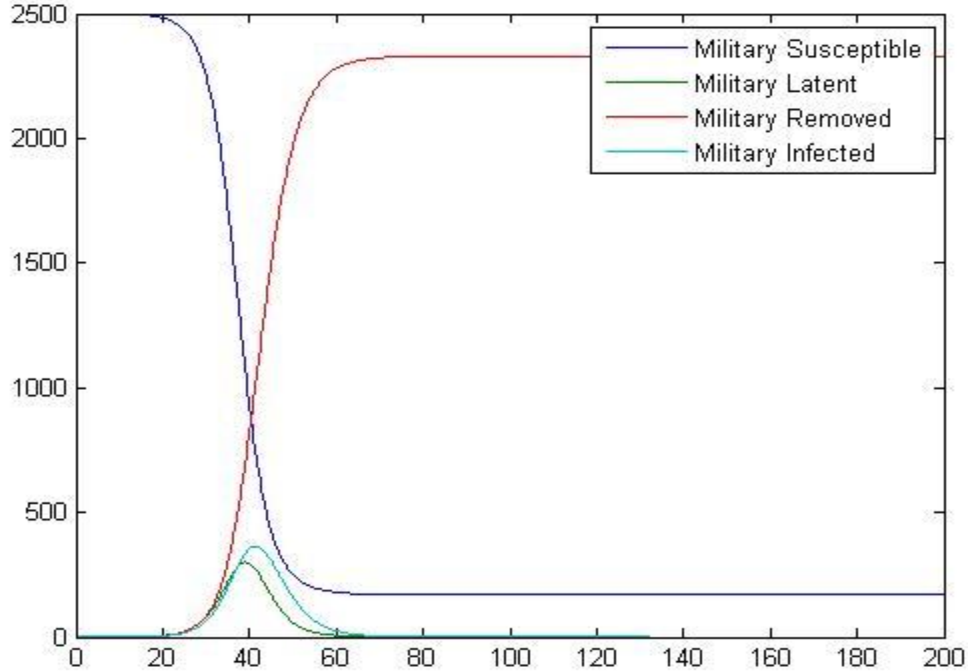
Greedy: People versus Time (Days) R_0 = 1.5



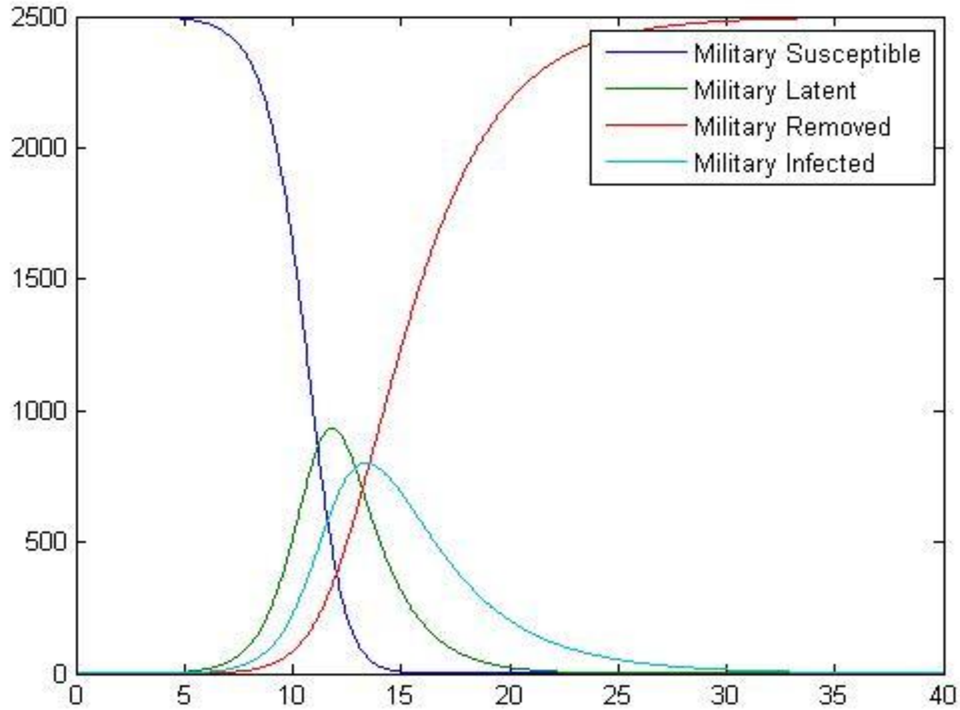
Greedy: People versus Time (Days) R_0 = 2.0



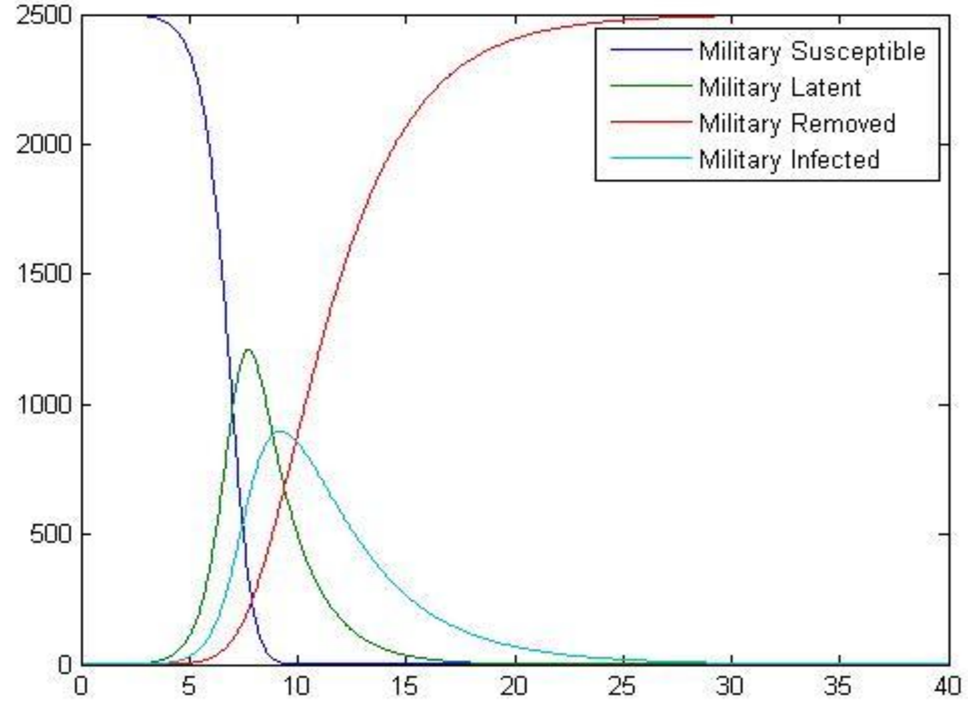
Cooperative: People versus Time (Days) R_0 = 1.1



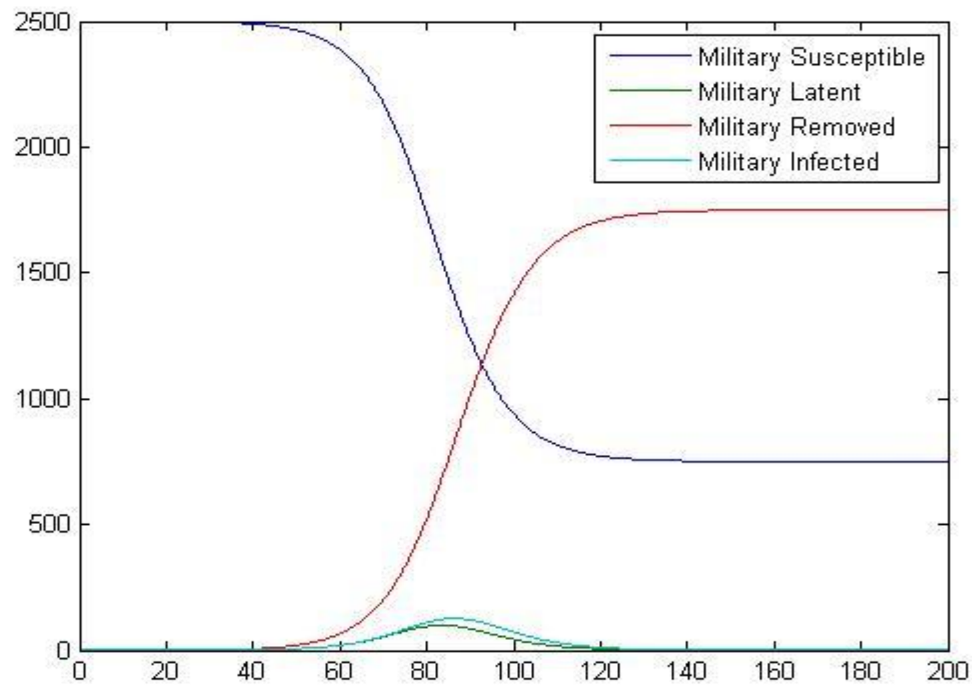
Cooperative: People versus Time (Days) R_0 = 1.5



Cooperative: People versus Time (Days) R_0 = 2.0



Equilibrium Example: People versus Time (Days) R_0 = 1.05



PART ONE AND TWO ENDNOTES

[1] See, for example, William C. Fox, "Phantom Warriors: Disease as a Threat to U.S. National Security," Parameters, winter (1997/98), in which he talks about "vast attacks on humans by a vast army of "phantom warriors"-viruses, bacteria, and parasites," 121.

[2] "The World Health Report 2007, Overview: Global Public Health Security in the 21st Century," World Health Organization, 3. The United States has increasingly recognized the links between national security and global health. See for example, the comprehensive report, "The Global infectious Disease Threat and Its Implications for the United States," available in its entirety online at http://www.cia.gov/cia/publications/nie/report/nie99-17d.html.

[3] Idem.

[4] For a thorough discussion of health and U.S. national security and information needs concerning global public health, see the groundbreaking Rand report, Gary Cecchine and Melinda Moore, "Infectious Disease and National Security: Strategic Information Needs," Rand , 2006.

[5] Sarah M. Glasgow, "Fighting the Last War: Human Security and the Threat of Infectious Disease," unpublished paper presented at the annual Convention of the International Studies Association, San Francisco, CA, March 2008. See for example Jessica Matthews, "Redefining Security," Foreign Affairs 68:2 (1989). See also, David P. Fidler, "Public Health and national Security in the Global Age: Infectious Diseases, Bioterrorism, and Realpolitik," George Washington International Law Review, available online at http"//findarticles.com/p/articles/mi_qa5433/is_200301/ai_n21341887.

[6] David P. Fidler, op.cit., 21.

[7] "The World Health Report 2007, 14.

[8]"The World Health Report 2007, 2.

[9] Richard F. Pilch, consultations May-June 2008. Dr. Pilch is considered one of the top experts in the world on biological threats, and his assistance with this paper was invaluable. He is currently in charge of developing a health surveillance system for Azerbaijan.

[10] Pilch, R., "Global Issues: Arms Control Measures," in Heggenhougen, H.K., Encyclopedia of Public Health (San Diego: Elsevier Inc., 2008).

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[12] For a detailed discussion of this program, see Pilch, R. & Zilinskas, R.A., "Threat Reduction in the Former Soviet Union," in Pilch, R. and Zilinskas, R.A., eds., The Encyclopedia of Bioterrorism Defense, New York: J. Wiley & Sons, 468-475. See also United States Government Accountability Office (2005), "Cooperative Threat Reduction," GAO 05-329 and Ball, D.Y. & Gerber, T.P., "Russian Scientists and Rogue States," International Security 29:4: 50-77.

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[44] CDC Fact Sheet on Drug Resistant Tuberculosis, available online at http://www.cdc.gov/tb/pubs/tbfactsheets/xdrtb.htm.
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XDR-TB is considered to be a virtually "untreatable" disease at the present time.
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PART THREE ENDNOTES

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