Tracking the Tiny Bugs:
Epidemic Models for Wargaming

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Executive Summary

The United States (US) Army faces a critical vulnerability due to its insufficient epidemic modeling capabilities. This deficiency hinders the accurate assessment of disease outbreak impacts on force readiness, operational timelines, and strategic objectives. Without robust modeling, resource allocation for medical needs becomes reactive, and the ability to evaluate mitigation strategies is critically limited.

This white paper analyzes the urgency of integrating advanced epidemic modeling into Army planning, training, and operations. It examines various epidemic models, including compartmental, agent-based, network, and hybrid models, highlighting their strengths and limitations for different scenarios.

KEY RECOMMENDATIONS:

- Establish an Epidemic Modeling Center of Excellence (EMCE): This centralized hub would develop, integrate, and operationalize epidemic modeling across all Army levels.
    - Focus on developing advanced modeling capabilities, integrating models into doctrine and wargaming, fostering collaboration and data sharing, and recruiting/training specialized personnel.
- Adapt Existing and Develop Future Wargames:
    - Modify current wargames to incorporate realistic disease outbreaks and their operational impacts.
    - Design future wargames with epidemic models as core components, incorporating expertise from epidemiologists and public health experts.

Developing robust epidemic modeling capabilities is crucial for maintaining military readiness and strategic advantage in an increasingly complex world. By establishing the EMCE and transforming wargaming methodologies, the Army can proactively address the threat of infectious diseases, ensuring force readiness, and global leadership in the face of biological threats.

Problem Statement

The US Army, despite its dedication to readiness and anticipating future threats, currently lacks a sufficiently robust and integrated epidemic modeling capability. This deficiency presents a critical vulnerability in an increasingly complex and inter-connected world where infectious disease outbreaks have the potential to disrupt operations, degrade combat power, and undermine national security.

This lack of sophisticated epidemic modeling hampers the Army's ability to accurately assess the impact of disease outbreaks on force readiness, operational timelines, and strategic objectives.[1] Without data-driven projections, resource allocation for medical personnel, equipment, and vaccines becomes reactive rather than informed, potentially leading to shortages and delays. Furthermore, the Army's ability to comprehensively compare the effectiveness of various mitigation measures like quarantine, vaccination, and treatment in different operational environments is severely limited, hindering its ability to minimize the impact of outbreaks on mission success.[2] Critically, the lack of integration between epidemic models and existing wargames prevents commanders from adequately preparing for the challenges of operating in a disease-affected battlespace.

Without a dedicated effort to develop and integrate advanced epidemic modeling capabilities, the Army risks being caught flat-footed in the face of a future pandemic or deliberate biological attack. This lack of foresight could lead to degraded readiness and ultimately mission failure due to unforeseen disease outbreaks impacting troop strength and logistical capabilities. Ultimately, inadequate preparation and response could result in increased casualties among service members and the populations they are sworn to protect. Such vulnerabilities risk diminishing global influence and credibility as the US military is perceived as susceptible to a threat that transcends traditional warfare. The Army must prioritize the development and integration of robust epidemic modeling into its planning, training, and operational doctrines to effectively counter this emerging threat and maintain its global leadership role in an increasingly uncertain world.

Background

Modern warfare extends beyond traditional battlefields. The rise of global connectivity and the potential for devastating pandemics necessitate incorporating biological threats into strategic planning and wargaming. Epidemic models provide the tools to simulate disease outbreaks, analyze their potential impact, and evaluate the effectiveness of various intervention strategies.

Despite significant advances in epidemiological modeling, wargaming has yet to fully incorporate these sophisticated tools into their simulations. While the need to address biological threats in military planning is increasingly recognized, wargames remain largely focused on traditional kinetic warfare. This disconnect stems from several factors, including the inherent complexity of integrating data-intensive epidemic models into existing wargame structures, concerns about data security and sharing, and a lack of interdisciplinary collaboration between modelers and wargame developers. Furthermore, there's a reluctance to deviate from familiar, combat-centric scenarios, overlooking the potential strategic disruptions posed by disease outbreaks. This lag in integrating realistic disease dynamics into wargames represents a critical vulnerability, leaving military planners inadequately prepared for the complex challenges of operating in a future shaped by pandemics and bio-threats.

Ironically, while sophisticated epidemic models struggle to find a place in military wargames, the gaming community has embraced the complexities of disease dynamics. Games like "Plague Inc." and "Pandemic" have captivated millions with their realistic portrayals of disease spread, resource management, and strategic decision-making during outbreaks.[3] These games demonstrate a public fascination with epidemiological challenges and highlight the potential for interactive simulations to educate and engage audiences on complex scientific concepts. This stark contrast underscores a crucial point: while military wargaming lags behind in embracing advanced epidemic models, the gaming industry demonstrates that engaging and informative simulations of disease outbreaks are not only possible but highly sought after. This disparity highlights a missed opportunity for the defense community to leverage similar approaches for training, planning, and public outreach in an era where biological threats are increasingly prominent.

Options for Epidemic Models

Today, as the world grows increasingly interconnected, understanding the dynamics of disease transmission is more critical than ever. Epidemic models provide a powerful lens through which the Army can study how diseases spread, predict their potential impact, and evaluate strategies to mitigate their effects. From simple compartmental models to complex agent-based simulations, each approach offers a unique tool on the dynamics of disease transmission and provides crucial information for training, exercises, and informed decision-making in the face of outbreaks.

COMPARTMENTAL MODELS:

The classic Susceptible-Infected-Recovered (SIR) model divides the population into three compartments, tracking the flow of individuals between them based on infection and recovery rates.[4] Simple to implement, it provides a basic understanding of epidemic dynamics.

While easy to understand and computationally inexpensive and rapid, it assumes a homogeneous population and constant transmission rates, limiting its realism. The Susceptible-Exposed-Infected-Recovered (SEIR) model adds an “Exposed” compartment, acknowledging the delay between exposure and infectedness or disease onset, offering a more realistic representation of diseases with incubation periods. Numerous variations exist, incorporating factors like age structure, spatial heterogeneity, waning immunity, and different transmission pathways.

AGENT-BASED MODELS (ABM):

These models simulate individual “agents” with unique characteristics and behaviors.[5] These agents interact within a defined environment, allowing for complex and emergent patterns of disease spread. ABMs provide a high level of detail and realism, capturing individual behaviors and interactions, making them suitable for heterogeneous populations and complex environments. However, they are computationally expensive and require extensive data and parameterization.

NETWORK MODELS:

Network models represent individuals as nodes and their interactions as links.[6] This approach allows researchers to move beyond individual risk factors and analyze how social structures and contact patterns influence transmission. The strength of network models lies in their ability to capture the complexities of social dynamics, identifying high-risk individuals and informing targeted interventions. For instance, analyzing contact networks could help predict influenza outbreaks within Army bases and logistical chains. However, building these models presents challenges. Obtaining detailed data on individual interactions can be difficult, and analyzing large, complex networks demands significant computational power. Additionally, accurately representing the dynamic nature of real-world networks and estimating transmission probabilities across diverse interactions requires careful consideration. Despite these challenges, network models are crucial for understanding disease spread and will become increasingly important in shaping Army health policies as data availability and computational capabilities advance.

HYBRID MODELS:

Hybrid models combine elements from different approaches to leverage their respective strengths.[7] For example, an ABM can be integrated with a network model to simulate disease spread within a specific structure, such as logistical nodes or maneuver elements. This offers increased realism and flexibility, allowing for tailored solutions. However, they can be complex to develop and implement.

Analysis

The selection of an appropriate epidemic model for wargaming is based on the specific objectives and constraints of the exercise. While using a more realistic and complex model is preferred, the optimal choice hinges on aligning model complexity to addressing the objectives and scope of the exercise.

For high-level strategic planning, where the focus lies in broad trends and long-term impacts on force posture and resource allocation, simpler compartmental models, such as SIR or SEIR, often provide sufficient insight. These models offer a valuable but generalized perspective on potential force readiness and strategic mobility constraints imposed by an epidemic. However, when transitioning to the operational level, where the emphasis shifts to planning specific campaigns and evaluating the efficacy of intervention strategies within a defined theater, the need for greater model sophistication is required to account for the unique factors at this level that can have a large impact on disease spread. In these cases, incorporating age structure, spatial components, or even metapopulation dynamics into SEIR models becomes essential for assessing the effectiveness of measures like quarantine zones, targeted vaccination campaigns, or medical surge capacity.

At the tactical level, where simulating the intricate interplay between disease propagation and on-the-ground decision-making is needed, agent-based models (ABMs) and network-based models are the program of choice. ABMs and network models excel in capturing the granular details of individual behavior among soldiers, enemy combatants, and civilians, while accounting for the influence of terrain, infrastructure, and unit-level interventions. However, this granularity comes at the cost of computational expense, calculation speed, and data requirements, so an evaluation of available resources and time constraints must be conducted.

Ultimately, the most effective model is not necessarily the most complex, but rather the one that strikes an optimal balance between realism, practicality, and the specific objectives of the wargame. A thorough assessment of data availability, computational resources, and the need for clear communication of model outputs to decision-makers should guide this selection process. By navigating these considerations, wargame designers can ensure their chosen model yields the most relevant and actionable insights for navigating the complexities of disease outbreaks within the Army.

Recommendation

To address the critical vulnerability posed by the lack of robust epidemic modeling capability, the US Army should establish a dedicated EMCE. This centralized hub would serve as the driving force for developing, integrating, and operationalizing epidemic modeling across all levels of Army planning, training, and response.

The EMCE would focus on the following key tasks:

1. **Develop and Maintain Advanced Modeling Capabilities:**

    b. Consolidate existing modeling efforts and expertise under a unified command structure.

    c. Invest in cutting-edge modeling tools and technologies, including artificial intelligence and machine learning, to enhance predictive accuracy and scenario analysis.

    d. Create a library of adaptable disease models tailorable to specific geographic regions, current threat scenarios, current intelligence reporting, and operational environments.

2. **Integrate Epidemic Modeling into Army Doctrine and Wargaming:**

    a. Modify existing wargames and training exercises specifically designed to incorporate realistic disease outbreaks and their impact on operations.

    b. Develop standardized doctrine and training materials to educate commanders and staff on interpreting and utilizing epidemic modeling outputs for decision-making.

    c. Establish clear lines of communication between modelers and military planners to ensure relevant and timely integration of modeling insights.

3. **Foster Collaboration and Data Sharing:**

    a. Build strong partnerships with civilian institutions, including universities, research labs, and public health agencies, to leverage existing expertise and data resources.

    b. Establish secure data-sharing agreements to facilitate access to real-time epidemiological data, both domestically and internationally.

4. **Recruit and Train Specialized Personnel:**

    a. Utilize appropriate Functional Areas (FAs) and Military Occupational Specialties within the Army for epidemic modeling experts, including opportunities for advanced education and research. These experts include FA52 Nuclear and Countering Weapons of Mass Destruction (CWMD) Officers, FA57 Simulation Officers, FA59 Strategists, 61G Infection Disease Officers, 71A Microbiology Officers, 71B Biochemistry Officers, and 740A Chemical, Biological, Radiological, and Nuclear Warrant Officers)

    b. Implement a comprehensive training program for existing personnel to develop a cadre of officers and analysts proficient in applying epidemic modeling to military planning and operations.

By establishing the EMCE, the Army can proactively address the growing threat of infectious disease outbreaks, ensure the readiness of its forces to operate effectively in a range of biological threat environments, and maintain its strategic advantage in an increasingly complex world.

Conclusion

The integration of epidemic models into the wargaming environment necessitates a multifaceted approach encompassing the adaptation of existing frameworks and proactive engagement in the development of future systems. Current wargames, often built around traditional kinetic and maneuver warfare architextures, need to be modified to accommodate the complexities of disease propagation. This includes not only the technical integration of chosen models, ensuring data exchange and synchronization with existing simulations, but also the development of user interfaces that render model outputs readily interpretable for planners accustomed to conventional wargaming outputs.

Beyond simply grafting epidemic models onto existing structures, a more impactful approach lies in embedding these models as core components of future wargame design. This requires a paradigm shift within the wargaming community, recognizing epidemiologists, data scientists, and public health experts as essential stakeholders in the design process. By engaging these organizations from the outset, future wargames can move beyond rudimentary representations of disease outbreaks to incorporate nuanced factors such as pathogen evolution, network dynamics, and the interplay between disease and human behavior on the battlefield. This collaborative approach, bridging the gap between biodefense experts at United States Army Nuclear and CWMD Agency (USANCA) and the Center for Army Analysis community, holds the key to developing wargaming environments that accurately reflect the multifaceted challenges of warfare defined by biological threats. Such a transformation in wargaming methodology is essential not only for maintaining military readiness in the face of pandemics but also for informing broader responses to global health security challenges. ■

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Notes

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