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Quantitative Models to Assess the Operational Impact of Biosurveillance and Early Warning of Infectious Disease

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Summary

- Biosurveillance systems need to respond to a range of scenarios
- A stochastic disease model has been developed that is adaptable for different scenarios and enables quantification of optimal information timing and response utility
- These outputs support optimization of biosurveillance architecture development and prioritization of R&D

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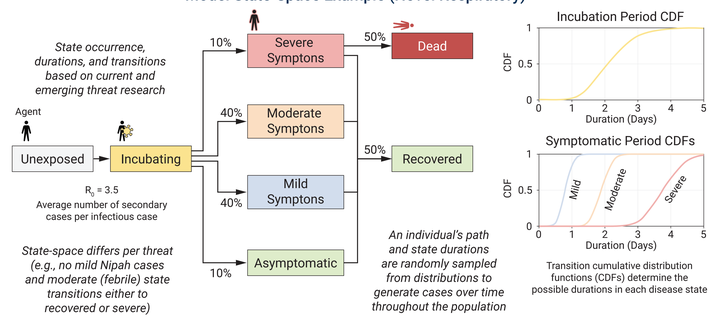
Motivation

Force readiness depends on our ability to detect, understand, and respond to a variety of biological threats before they compromise mission success. It is a priority of the DoW to develop biosurveillance capabilities to protect force health and mission effectiveness.

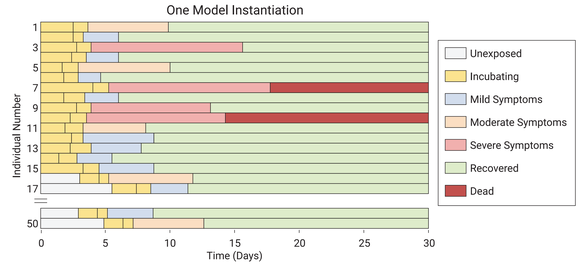
To support this priority:
- A stochastic model has been developed to simulate disease progression and to quantify operational impact and response effectiveness as a function of response initiation time
- Outputs from the modeling framework support the development and refinement of biosurveillance architectures and the prioritization of capability development to maximize force readiness.

Disease Model

Model State-Space Example (Novel Respiratory)



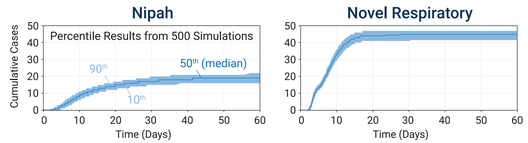
Operational Scenario: 50 Soldiers with 15 Initial Exposures



Model tracks individual's disease state over time; each simulation results in a different distribution of symptom severities and individuals exposed over time

Threats Modeled

Mission impact, response options, and response timelines differ by disease, highlighting the need to assess biosurveillance across the full range of disease threats



	Nipah	Novel Respiratory
Summary	Zoonotic disease transmitted from animals, through contaminated food, or human-to-human contact; can lead to acute respiratory illness and encephalitis (brain swelling)	Theoretical (hypothetical) influenza-like illness informed by comparing influenza against a range of challenging respiratory disease characteristics (e.g., MERS, avian flu)
Contagiousness	Symptomatic only 0.48 R_0	~ 2 days to 1 week post symptoms; 8% of asymptomatic; 3.5 R_0
Severity	90% hospitalized; ~58% fatal	10% hospitalized; 5% fatal

Detect and Mitigate

Shared biosurveillance information will lag initial detections which depend on specific threat progression

Earliest Detection

Data/Info Type	Detection Timing Assumptions
Environmental Sensors	Potentially available at exposure (depending on pathogen)
Syndromic	Reporting occurs upon symptom onset
Clinical Diagnosis	• First severe case (field forward) + time to access diagnostic technologies • First fatality + reporting delay
Sequencing	First severe case + time to sequence and analyze results

Estimate timelines for different information types to become available based on scenario context, resource availability, and specific threat progression.

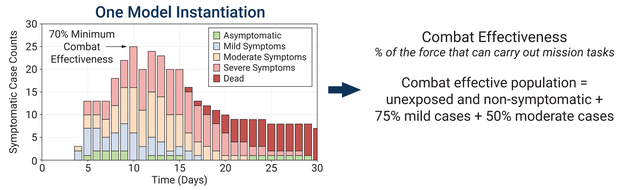
Response options differ depending on threat and current state of countermeasures

Response Options

Option	Estimated Effectiveness	Assumptions: Nipah	Assumptions: Novel Respiratory
Non-Pharmacological (NP) Intervention	80% reduced infectious contact (e.g., N95 masking)	Applied 100% compliant population; proper use	Applied 90% compliant population; proper use
Cohorting/ Isolation	100% reduced infectious contact	Applied by 100% compliant, symptomatic population	Applied by 90% compliant, symptomatic population
Antiviral Treatment	36% reduction in mortality and 1-day reduced symptom duration	Not applicable (No treatment exists)	Administered to symptomatic

Operational Impact Metrics

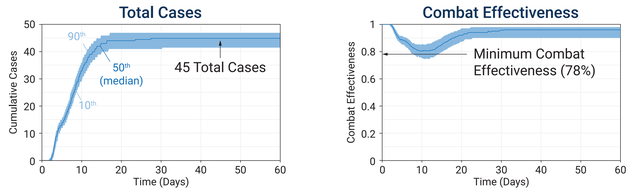
Metrics Example (Novel Respiratory Without Intervention)



Combat Effectiveness
% of the force that can carry out mission tasks

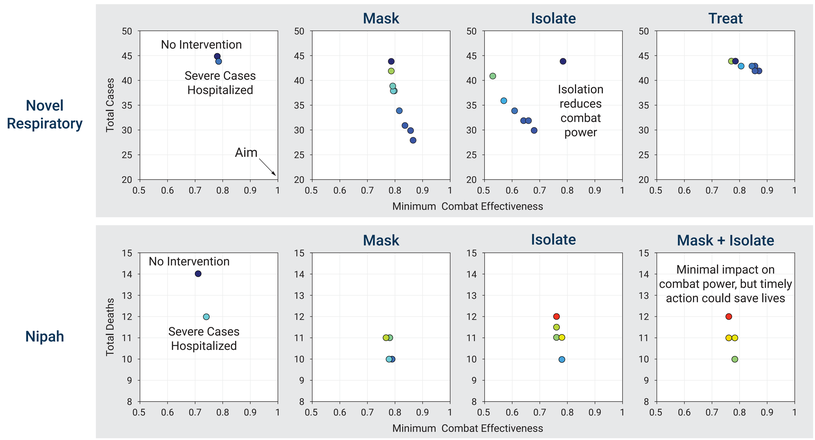
Combat effective population = unexposed and non-symptomatic + 75% mild cases + 50% moderate cases

Metrics derived from the 50th percentile of 500 simulations



Estimated Impact of Information Timing

Modeling results enable quantitative assessment of biological event impacts, response utility, and optimal information timing to maximize force readiness.



The model enables quantification of mission relevant impacts - e.g. the estimated improvement to minimum combat effectiveness (78% → 88%) and number of cases (45 → 26) as responses like masking are cued more rapidly for a novel respiratory outbreak.

These outputs extend understanding of current state, highlight the most impactful information sources across scenarios and prioritize future R&D needs.