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Methodology for Chemical or Biological Defense Capability Set Analyses

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Capability Set Analyses**

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Executive Summary

The Joint Requirements Office for Chemical, Biological, Radiological, and Nuclear Defense (JRO-CBRND) commissioned a potential series of defense capability set analyses to determine integrated capability sets for various chemical or biological (CB) threats. These integrated capability sets are a combination of capabilities and capability attributes that together create a layered defense against a given threat. To produce recommended integrated capability sets, we developed a methodology that includes the following steps:

1. Identify potential capabilities against the agent and their attributes (concurrent with step 2);
2. Identify illustrative, operationally relevant vignette(s) (concurrent with step 1);
3. Apply capabilities to the vignettes;
4. Use appropriate methods to define and quantify measures of effectiveness (MOEs) for each combination of capability set and vignette;
5. Identify the mathematically optimal capability set(s) for each vignette;
6. Apply operational constraints to determine the feasible capability set(s); and
7. Determine the recommended Key Performance Parameters (KPPs), Key System Attributes (KSAs), Initial Operational Capabilities (IOCs), and Full Operational Capabilities (FOCs) for feasible capability set(s), noting any interdependencies between different capabilities

This Institute for Defense Analyses paper summarizes this methodology and broadly describes how it could be repeated in support of future capability set analyses.

Contents

1. Methodology for Chemical or Biological (CB) Defense Capability Set Analyses	1
A. Identify Potential Capabilities and Their Attributes.....	3
B. Identify Vignettes	4
C. Apply Capabilities to the Vignettes.....	5
D. Define and Quantify MOEs.....	6
1. Identify Stochastic Elements	7
2. Assess Operational Impacts of Capability Sets	8
E. Identify Mathematically Optimal Capability Set(s) for Each Vignette.....	8
1. Determine Optimal Capability Set(s).....	8
2. Identify Critical and Non-critical Capabilities	10
F. Determine Operationally Feasible Capability Set(s).....	11
G. Determine the Recommended KPPs, KSAs, IOCs, and FOCs	11
2. Conclusions	13
Appendix A. Illustrations.....	A-1
Appendix B. References	B-1
Appendix C. Abbreviations	C-1

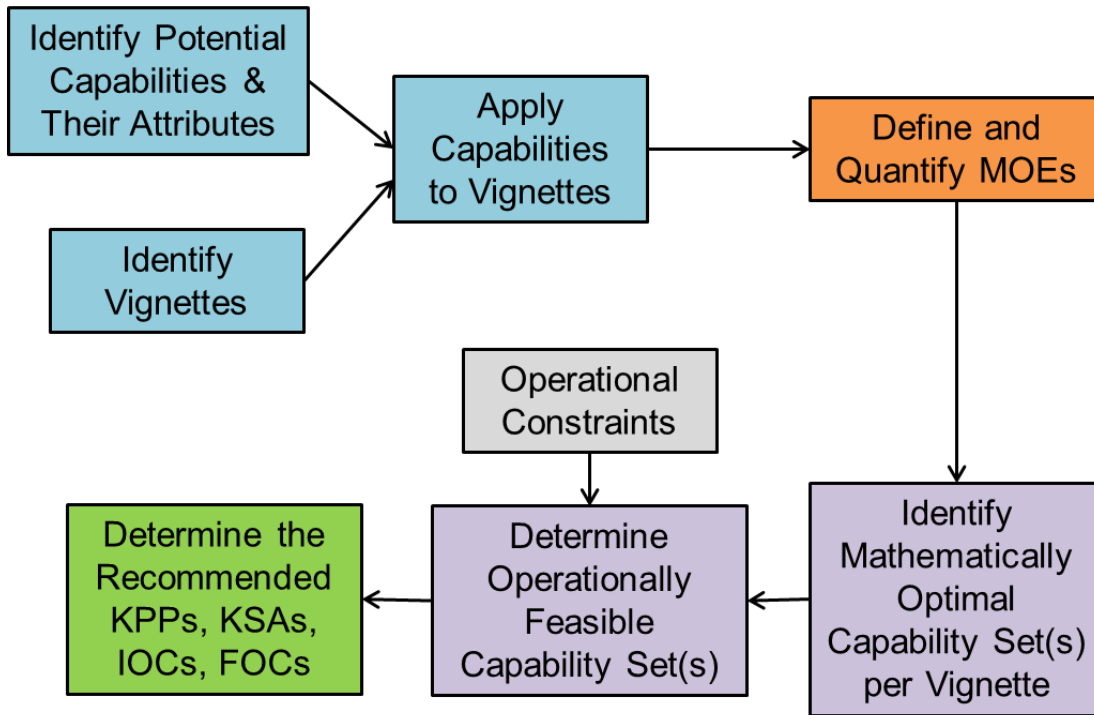
1. Methodology for Chemical or Biological (CB) Defense Capability Set Analyses

Starting in 2019, the Joint Requirements Office for Chemical, Biological, Radiological, and Nuclear Defense (JRO-CBRND) commissioned a potential series of chemical or biological (CB) defense capability set analyses to determine recommended integrated capability sets for various CB threats.¹ A capability set is defined as a combination of capabilities wherein each capability has defined performance parameters and other attributes² that can be used to define the performance of the package of capabilities. By examining all capabilities for a given threat as a cohesive strategy, such an analysis can determine how to most efficiently and effectively combine all capabilities and identify the most important attributes of each capability to mitigate a given threat. The first in this capability set analysis series was featured in Institute for Defense Analyses (IDA) Paper P-14277.³ Although the majority of that analysis was specific to filoviruses, the overall methodology can be applied to capability set analyses for any CB threat. Figure 1 contains the overall methodology shown in IDA Paper P-14277, with a few adaptations to make it even more generalizable. In the figure, blue boxes indicate steps that involve capabilities or vignettes, orange boxes are for measure of effectiveness (MOEs), purple boxes indicate steps associated with developing capability sets, and green boxes are for Key Performance Parameters (KPPs), Key System Attributes (KSAs), Initial Operational Capabilities (IOCs), and Full Operational Capabilities (FOCs). Arrows indicate the flow through the process. The first steps identify capabilities and vignettes, and the last step identifies KPPs, KSAs, IOCs, and FOCs.

¹ A chemical or biological (CB) threat could include any disease or chemical agent that is of importance for developing defensive capabilities (e.g., contagious or non-contagious diseases, persistent or non-persistent chemicals, and so forth.)

² Capability attributes could include parameters such as efficacy, time to effect, or ease of use. Some attributes, but not all, can be defined by Key Performance Parameters (KPPs) and Key System Attributes (KSAs).

³ Kristen A. Bishop et al., *Filovirus Defense Capability Set Analysis*, IDA Paper P-14277 (Alexandria, VA: Institute for Defense Analyses, December 2020), SECRET//NOFORN. Only UNCLASSIFIED information is included in this paper.



Source: Adapted from Kristen A. Bishop et al., *Filovirus Defense Capability Set Analysis*, IDA Paper P-14277 (Alexandria, VA: Institute for Defense Analyses, December 2020), 4, SECRET//NOFORN. Only UNCLASSIFIED information is included in this report.

Note: The abbreviations used in this figure are defined in Appendix C.

Figure 1. Methodology Process

This paper summarizes the methodology and broadly describes how it could be applied to future capability set analyses. The steps discussed in each section of this methodology are as follows:

1. Identify potential capabilities against the agent and their attributes (concurrent with step 2);
2. Identify illustrative, operationally relevant vignette(s) (concurrent with step 1);
3. Apply capabilities to the vignettes;
4. Use appropriate methods to define and quantify measures of effectiveness (MOEs) for each combination of capability set and vignette;
5. Identify the mathematically optimal capability set(s) for each vignette;
6. Apply operational constraints to determine the feasible capability set(s); and
7. Determine the recommended KPPs, KSAs, IOCs, and FOCs (defined in Sections D and G) for feasible capability set(s), noting any interdependencies between different capabilities.

A. Identify Potential Capabilities and Their Attributes

An important component of layered defense is having a varied array of potential capabilities against a given threat so that these capabilities can be combined effectively and prevent and/or mitigate the effects from that threat. When determining relevant capabilities, a number of categories should be considered: medical and non-medical capabilities and materiel and non-materiel capabilities. Medical capabilities may include medical countermeasures (MCMs) (e.g., antibiotics, antivirals, vaccines), clinical diagnostic tests, and supportive or non-specific care (e.g., pain management, fluid replacement, oxygen). Non-medical capabilities may include protective equipment (e.g., personal protective equipment (PPE) or mission-oriented protective posture (MOPP) gear); detection and identification devices; warning, reporting, and hazard prediction systems; and decontamination supplies. Some medical and non-medical capabilities could also be non-materiel capabilities. Non-materiel capabilities may include intelligence gathering, restriction of movement (including quarantine and isolation), sufficient personnel staffing, and materiel distribution systems. Capabilities may vary for different agents in consideration (e.g., a contagious biological agent, a non-contagious biological agent, a persistent chemical agent, or a non-persistent chemical agent); however, these categories generally represent the range of potential capabilities that might be applied to any of these agents, and they can be removed from analytical consideration if they are not applicable for a given agent.

The different levels of capability applicability range from threat-agnostic capabilities to highly threat-specific capabilities. For example, MOPP gear can protect against a variety of chemical and biological agents, while a vaccine typically only works against one specific disease. In addition to broad and specific capabilities, interdependencies must be noted and included in the analysis (i.e., certain capabilities may rely on others to be fully effective). These interdependencies can provide context for an identified capability set and could allow the JRO-CBRND to identify the capabilities on which many other capabilities are reliant. Concepts of operation (CONOPS) developed for previous Capability Based Assessments (CBAs), such as the Pathogens CBA⁴ or the Toxic Threats CBA,⁵ can provide good starting points to ensure that all potential capabilities are considered.

A variety of capabilities may currently exist against the agent of interest. In addition to considering these current capabilities, it is also important to consider potential future capabilities. Potential future capabilities could be gleaned from capabilities currently in development against that agent or could be extrapolated from current capabilities. For

⁴ Mark E. Bohannon et al., *Countering Biological Warfare (BW) Pathogens Concept, Pt. 1*, IDA Paper P-10398 (Alexandria, VA: Institute for Defense Analyses, February 2019).

⁵ Mark E. Bohannon et al., *Countering Toxic Threats with Medical Countermeasures Concept of Operations (CONOPS)*, IDA Paper P-10718 (Alexandria, VA: Institute for Defense Analyses, August 2019).

example, a future vaccine may have a higher efficacy than the current vaccine for a given agent. A number of capabilities may exist, but the capabilities considered need to be bounded so that only relevant and realistic capabilities for the time frame of interest (current or future) are included in any analysis. Realistic current capabilities typically should be approved or validated, currently fielded or readily fielded, and widely available. Realistic future capabilities should have those same characteristics by the future time frame of interest. Current experimental capabilities may not be realistic for current use but may be viable to consider as future capabilities.

B. Identify Vignettes

A given CB threat could be encountered in a variety of different scenarios or vignettes. Operationally relevant vignettes for an agent can be determined by first looking at the threat analyses for the agent/agent category of interest or related agent/agent categories if threat analyses for the chosen agent are unavailable and the threat assessments for relevant adversaries. This combination of agent and adversary threat assessments provides insight into how the agent can be employed or in which theaters the agent could be employed. If the threat environment is likely to change within the time frame of interest, that change should be reflected in the vignettes chosen. In addition, some vignettes for certain agents may already be available from past tabletop exercises (TTXs)⁶ or other efforts.

A given capability set may be optimal for a particular vignette but not for all vignettes. When possible, a range of vignettes should be included to show the breadth of potential situations in which the agent could be encountered and to determine how individual capabilities may be more or less useful in each situation. In addition, when possible, the likelihood of different vignettes should be assessed, especially for cases where different capability sets are optimal for different vignettes. This concept is discussed further in Section E.1.

Some broad categories of vignettes that could be used in defense solution studies include covert or overt attacks and large or small attacks. Whether an adversary employs a covert or an overt attack could change which capabilities are available to our forces, as discussed in Section C. In addition, a large attack could affect the number of casualties or the extent of other operational impacts or MOEs (e.g., areas requiring decontamination) differently when compared to a small attack. To the degree possible, vignettes for different services should also be included to facilitate the generation of IOC and FOC values (see Section G) and to consider how the threat can be encountered differently by each service.

⁶ For example, Cassandra TTXs are hosted periodically by the JRO and include vignettes illustrating different aspects of chemical, biological, radiological, and nuclear (CBRN) defense.

Where possible, vignettes should be sufficiently detailed so that they include information such as agent or dissemination parameters, operational level descriptions, or local variables (e.g., meteorological conditions). This information can help guide the quantification of MOEs, such as providing parameters for transport and dispersion modeling. Other information, such as operational level descriptions, can influence the MOEs related to operational impacts.

C. Apply Capabilities to the Vignettes

Once the capabilities have been identified, they must be applied to the vignettes by determining which capabilities are relevant to a given scenario. While many capabilities may exist, only a subset may be applicable to a certain vignette. For example, if a vignette occurs in an austere environment, then capabilities that would require continuous refrigeration or power sources may not be available. Furthermore, each capability may have multiple attributes that are quantifiable; however, only a subset of those attributes may be relevant and only those attributes should be used to describe the impact of a capability in a specific vignette. This situation depends largely on the intersection of the capability and the vignette and the operational impacts associated with an attack on a given vignette. Any assumptions related to the capability should be described.

Some capabilities may have attributes with particular variations, each of which are relevant to the scenario. Including different “levels” of a given capability’s attribute can provide insight into the extent of the impact which that particular capability has on a given vignette. For example, if multiple vaccines exist for a biological agent and each has a different efficacy, including at least two efficacies that represent the range of possibilities can illustrate how large (or minimal) the impact of a vaccine is on a certain vignette. If only one capability “level” is available, representing that “level” alone is still useful because it can potentially show how future capabilities could or should fill a gap. These “levels” can also inform KPP and KSA values (see Section G).

Some capabilities can be included within all possible capability sets for a given vignette, while some capabilities can only be included in some of a vignette’s capability sets. Capabilities that are included in all possible capability sets are typically those that would be employed at all times regardless of the threat (e.g., supportive care). Other capabilities, however, would be omitted from some capability sets to see whether they are critical or non-critical capabilities. Most capabilities would fall into the second category.

In addition, interdependencies between capabilities may impact their utility. One example would be that if one capability must exist for another to be effective, then the capability set for a given vignette must reflect that interdependency. For example, to use MOPP gear effectively, there must be some prior indication that an attack is imminent or that an area is contaminated, usually via detection. Thus, capability sets may include MOPP

gear only if detection is also present in that set. Many other interdependencies can be discovered or noted when determining optimal or feasible capability sets (see Sections E and F). Two capabilities may act on the same MOE, and therefore the efficacy requirements for one may be dependent on the efficacy requirements for the other. An example would be vaccines and post-exposure prophylaxis (PEP), both of which work to prevent casualties from a disease exposure. The utility of one capability may be dependent upon another capability's attributes (e.g., the benefit from a treatment may be dependent on how quickly a diagnostic result can be determined). Many of these interdependencies can be noted early in the process but can be better analyzed via quantifying MOEs and determining optimum and feasible capability sets.

D. Define and Quantify MOEs

After relevant capabilities have been identified for each vignette, MOEs must be identified to quantify the effects of the capabilities within each vignette. MOEs that have operational impacts are especially relevant. For example, the number of casualties can influence an operation, while the percentage of casualties who become fatalities, although still important, typically does not influence an operation. MOEs for capabilities should be quantifiable for individual capabilities and for capability sets so that numerical values can be assigned to the MOEs for each capability set. Specific attributes of the capabilities that are not captured by MOEs should also be quantified where possible. These attributes could influence the utility of a given capability and how that capability could be integrated within the set. Some of these attributes could have a binary quantification (e.g., "1 for present, 0 for absent"), while others could have multiple values (e.g., values from 0 to 100%). This quantification could include metrics such as the time to produce a desired effect, efficacy, or the frequency of use. These quantitative attributes can be used to help determine KPPs and KSAs (see Section G). KPP metrics are those considered essential to achieve the goals of the capability, while KSA metrics are those considered important but not critical to achieve the goals of the capability.

The most appropriate MOEs may be different for each capability or agent under consideration. For example, the extent of contamination may be an important MOE for persistent chemicals but may not be relevant for non-persistent chemicals. The type of MOE can influence the method of quantifying the MOE.

MOEs can be quantified in several ways. Models can be particularly effective in quantifying certain MOEs, but these models are by no means the only or most appropriate method for every analytical situation. One way to quantify MOEs is to use computer simulations to represent each element of the capability set as a system (including interdependencies) in the context of each vignette. Computer simulations could include contagious disease, atmospheric transport and dispersion, or other phenomena and would be determined based on the agent and MOEs of interest. Using more subjective approaches

(e.g., voting schemes, utility estimates, and so forth) that rely on subjective methods of quantification is also possible. Previous experimental data could also be used directly in some instances. Whether computer simulations, subjective methods, hybrid approaches, or other methods are used, each capability considered must have the potential to impact at least one MOE, and MOEs must be expressed by a numerical value in each vignette for each capability set. The resulting values can be presented as shown in Table 1.

Table 1. Sample Quantification Result Presentation

Capability Set	Vignette 1			Vignette 2		
	MOE 1	MOE 2	MOE 3	MOE 1	MOE 2	MOE 3
C1	#	#	#	#	#	#
C2	#	#	#	#	#	#
...
Cn	#	#	#	#	#	#

Table 1 illustrates a case in which there are two vignettes and three MOEs that are evaluated for each of n capability sets. In general, n can be a large number, and the process of producing each entry in the table is a time-consuming operation, whether using a computer simulation or a subjective input. As a result, developing and verifying the quantification approach and executing it for each capability set can account for a substantial portion of the analysis.

1. Identify Stochastic Elements

Elements of the vignettes or capabilities, such as variations in adversary operations (e.g., targeting errors of artillery systems), capabilities (e.g., detection probabilities), or human responses (e.g., likelihood or timing of injury/illness), may be stochastic⁷. In these cases, examining the impact of distributions of the stochastic elements may be necessary. When using computer simulation quantification methods, Monte-Carlo approaches and the selection of relevant statistics (e.g., mean or a particular quantile) for use as MOEs may be required. A Monte-Carlo approach can be used to approximate the overall probability distribution of model output that represents the contribution of one or more stochastic elements so that statistics of interest can be derived when that overall distribution cannot be analytically described. The number of cases to be run for each capability set can increase significantly to generate reliable statistics, thus contributing to the level of effort required to conduct the quantification. This increased effort likely precludes human-generated subjective approaches.

⁷ Stochastic elements are those that are determined randomly from a distribution, not from fixed values.

2. Assess Operational Impacts of Capability Sets

After completing the appropriate quantitative analytical methods (e.g., computer modeling, subjective approaches, or other methods), the results should be assessed to determine which capabilities had a significant operational impact on the vignette outcome compared to a baseline where no capability candidates are included. MOEs related to operational impact are the most relevant, but some operational impacts may not be measured by the selected MOEs. In some instances, the operational impact may be related to different thresholds of an MOE (e.g., a threshold percentage of casualties or a threshold time to produce a desired effect). If an MOE has a threshold value, one should determine whether each capability set meets or fails to meet the threshold for that particular MOE. For example, if a threshold of an MOE is recognizing an outbreak of disease early enough to implement restriction of movement so the disease does not spread beyond the original unit, then capability sets that achieve that threshold value could avoid many operational impacts of disease spread.

Some capabilities may yield predictable or expected impacts, while others may have an unexpected impact (or lack thereof) on the outcome. Furthermore, some capabilities may have more significant impacts on certain MOEs or metrics than others. Considering these different outcomes and the drivers behind them can help to provide a complete and cohesive layered defense that appropriately considers all the nuances and interdependencies involved in each layer. Determining which MOEs or metrics are most important or relevant to a vignette will influence which capabilities are selected by the optimization and analysis processes for inclusion in the mathematically optimal and operationally feasible capability sets (discussed in Sections E and F).

E. Identify Mathematically Optimal Capability Set(s) for Each Vignette

1. Determine Optimal Capability Set(s)

The next step in the assessment process is to determine a mathematically optimal capability set based on the outcomes of the quantification described previously. A mathematically optimal set may not necessarily be the operationally optimal set. A mathematical optimization maximizes or minimizes an objective function, which may consist of a single MOE or is a function of MOEs that produces an output value to express the impact of the capabilities. When multiple MOEs and multiple vignettes have to be considered, expressing the mathematical optimization problem can be challenging. These challenges can be addressed in several ways:

- **Select a single MOE to optimize (maximize or minimize, as appropriate).**
This approach might be acceptable if a particular MOE is viewed as most important. The results from the MOEs can be viewed as topics for discussion or

can be converted into constraints for the optimization. For example, the optimal capability set may be the set that maximizes the first MOE, subject to all other MOEs being above a certain threshold.

- **Derive a comprehensive objective function.** One often-used approach is to apply weights to the MOEs that reflect their importance to the overarching problem so that the objective function is a linear sum of MOEs. This approach essentially combines the MOEs into a single value that can be maximized or minimized; however, the combined values must be an appropriate characterization of the results, and the MOEs should be suitably represented. For example, if probability of detection is one MOE (bounded by zero and one) and casualty count (bounded by zero and a very large number) is the other MOE, normalization may be required. Using weights adds the additional problem of defining correct weights. Weighted sums are not the only way to create an objective function, however. Any mathematical expression is a candidate, but, of course, not all expressions make sense within the context of the analysis.
- **Divide the analysis and determine optima for subsets of results (e.g., by using different MOEs as objective functions of subsets of MOEs or a separate weighting of MOEs in each vignette).** If this approach produces more than one optimal capability set, results can be presented to the ultimate decision maker to apply his or her own judgment as to which MOE is of greatest importance.
- **Apply a lexicographic approach, ordinally ranking each MOE in order of preferred importance ($MOE_1, MOE_2 \dots MOE_t$).**⁸ This approach would allow the capability sets that optimize for MOE_1 to be determined, and, from among them (if there is more than one), those capability sets that optimize for MOE_2 , and so forth. This approach is essentially one of sequential optimization but requires an acceptable ranking of MOEs from most important or relevant to least important or relevant with regard to the overall analysis.

The analyst conducting the mathematical optimization will determine which of these methods is appropriate or whether another method or a combination of methods should be used. In each of these approaches, more than one capability set may produce the same optimal value. If that is the case, other criteria (e.g., the number of capabilities involved, total cost of capabilities or some assessment of battlefield suitability) may be invoked to further distinguish among capability sets.

⁸ A lexicographic approach ranks the capability sets first by the first MOE's value (from most to least optimal) for M_1 , and then, within the set of equal values for the first MOE, ranks by the second MOE and so forth. By ranking the MOEs ordinally, one capability set is eventually determined to be in first place, another capability in second, and so forth.

Once a mathematically optimal capability set has been determined for each vignette, the capability sets across vignettes may need to be combined to create an overall capability set. In some instances, different capability sets may be required for different vignettes, and a single vignette may not be able to be prioritized over another. For example, if vignettes include different agents, then an optimal capability set may need to be defined for different agents rather than being applicable to all agents. Two ways of addressing the problem of multiple optimal capability sets are as follows:

- **Select a single vignette as the most important.** The results from the other vignettes can be viewed as topics for discussion or can be converted into constraints for the optimization. Consequently, the optimal capability set for the most important vignette would be chosen as the optimal capability set for the whole analysis. For example, the optimal capability combination could be the one from Vignette 1, assuming that a central MOE from Vignette 2 (e.g., shelf stability) is included.
- **Present an optimal set for each vignette to the decision maker so that he or she can apply his or her own preference as to which vignette is of greatest importance or can select multiple capability sets across vignettes.** As an example, capabilities may be appropriate in some vignettes but not in others (e.g., pre-exposure prophylaxis may be appropriate in vignettes based on threat agents for which vaccines exist or can be developed but not if it is unlikely that a vaccine can be developed). This problem can be addressed by having multiple optimal capability sets and determining the IOC/FOC requirements accordingly based on which vignettes require the capability.

2. Identify Critical and Non-critical Capabilities

The optimization process may reveal that certain capabilities or certain capability attributes never appear in an optimal capability set or do not have any influence on the MOEs. If the quantification procedure has been correctly constructed to reflect those capabilities, then it may be that such capabilities or capability attributes can be considered non-critical and removed from further consideration since their inclusion does not appear to provide benefit. However, non-critical capabilities may need to be reconsidered if capabilities or capability/performance combinations that appear in optimal capability sets are later discovered to be unachievable. Non-critical capabilities that are expected to influence MOEs in the absence of the unachievable capabilities may be more likely to become critical in that instance. Consideration of non-critical capabilities could also provide redundancy, which is desirable in situations where a critical capability is unable to be employed.

F. Determine Operationally Feasible Capability Set(s)

Once the mathematically optimal capability set(s) have been determined across the vignettes, the next step is to determine the recommended operationally feasible capability set(s). This step involves a tradeoff analysis that determines whether there are constraints on some MOEs that are less restrictive than the optimal value but are still operationally or qualitatively acceptable. Although the minimum/maximum MOE may be mathematically optimal, there may be little operational impact between the optimal value and one that is less restrictive. For example, if an MOE is the number of casualties, certain casualty thresholds may be qualitatively acceptable rather than requiring casualty numbers to be the lowest possible. To determine the operationally feasible capability sets, those capability sets that fulfill the less restrictive but qualitatively acceptable MOE thresholds should be included in the analysis. Then, the sets should be examined to determine how they are grouped and if there is one operationally feasible capability set that is the most desirable. When the process is complete, one operationally feasible capability set should become the recommended set, except in situations where different vignettes/agents require different recommended sets. In some instances, the operationally feasible capability set may include a range of possible attributes for some of the included capabilities, which could reflect the range of attributes that fulfill all acceptable MOE thresholds.

G. Determine the Recommended KPPs, KSAs, IOCs, and FOCs

Within the recommended operationally feasible capability sets, the important attributes of each capability should be documented as KPPs and KSAs, where relevant. Some capabilities, especially non-materiel capabilities, may not have associated KPPs or KSAs. Where possible, attributes of those capabilities that are important for their use within the operationally feasible capability set should still be quantitatively or qualitatively expressed.

Some KPPs and KSAs can be derived directly from the results of the feasible capability set analysis. For example, if multiple efficacy values of a given capability were included within the modeling, then the modeling results could inform efficacy KSAs by showing which efficacy values were used in the recommended feasible capability set. Where possible, capability attributes should be selected such that they can inform relevant KPPs and KSAs. Sometimes, the results of quantification can inform the KPPs or KSAs for a given capability without needing to initially input different parameters for that capability. For example, the model could output the time at which individuals receive PEP, which would inform the window during which PEP needs to be effective after initial infection.

Other KPPs and KSAs can be derived from modeling results or inputs outside of the analysis of what capabilities are included in the feasible capability set. For example, some KSAs (e.g., route of administration of an MCM) could be informed by the literature review

of what is possible in the desired time frame. That information, plus the outputs of the quantification, could be used for a KSA.

IOC and FOC values should be derived from the threat information, planning scenarios, and vignette information and from the results of the optimization analysis, especially in instances where there are different recommended capability solutions sets for different vignettes. For some capabilities (e.g., diagnostics or detectors), the IOC/FOC values may be tied to the number of units. For other capabilities (e.g., MOPP gear or vaccines), the IOC/FOC values may be tied to the number of personnel at risk. For other capabilities (e.g., PEP or therapeutics), the IOC/FOC values may be tied only to those personnel who are attacked or who become symptomatic, scaled by the number of attacks expected. The number of units or personnel in each of these categories can be derived from model results, vignette information, planning scenarios, and the threat. When capabilities are only critical in certain vignettes but not others, the IOC/FOC values should reflect that fact.

2. Conclusions

The methodology described in this report can generally be applied to almost any potential CB threat. Across some categories of agents (e.g., contagious biological agents or persistent chemical agents), there may be similar capabilities available and similar defense capability set results. Therefore, any results for a given CB threat should be presented in the context of how the results may be similar or different for other agents.

These defense capability set analyses will enable the JRO-CBRND to create capability development documents that are written in the context of all potential capabilities available. This approach should help avoid redundancy and ensure that the most important capabilities and capability attributes for reducing operational impact or supporting important MOEs are prioritized. It also helps streamline the capability development process and helps ensure that capabilities are not developed independent of each other.

Appendix A. Illustrations

Figure

Figure 1. Methodology Process	2
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Table

Table 1. Sample Quantification Result Presentation	7
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Appendix B. References

- Bishop, Kristen A., Robert L. Cubeta, Catherine E. Shuster, Jeffrey H. Grotte, Lucas A. LaViolet, and Jon M. Davis. *Filovirus Defense Capability Set Analysis*. IDA Paper P-14277. Alexandria, VA: Institute for Defense Analyses, December 2020. SECRET//NOFORN.
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Appendix C. Abbreviations

CB	chemical or biological
CBA	Capability Based Assessment
CBRN	chemical, biological, radiological, and nuclear
CONOPS	concepts of operation
FOC	Full Operational Capability
IDA	Institute for Defense Analyses
IOC	Initial Operational Capability
JRO	Joint Requirements Office
JRO-CBRND	Joint Requirements Office for Chemical, Biological, Radiological, and Nuclear Defense
KPP	Key Performance Parameter
KSA	Key System Attribute
MCM	medical countermeasure
MOE	measure of effectiveness
MOPP	mission-oriented protective posture
PEP	post-exposure prophylaxis
PPE	personal protective equipment
TTX	tabletop exercise

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