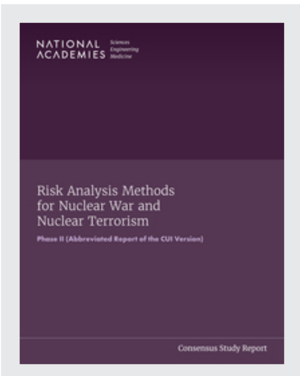

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Phase II (Abbreviated Report of the CUI Version)

Committee on Risk Analysis Methods for Nuclear War and Nuclear Terrorism

Board on Mathematical Sciences and Analytics
Division on Engineering and Physical Sciences

Nuclear and Radiation Studies Board
Division on Earth and Life Studies

Committee on International Security and Arms Control
Policy and Global Affairs

Consensus Study Report

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This Consensus Study Report was reviewed in draft form by individuals chosen for their diverse perspectives and technical expertise. The purpose of this independent review is to provide candid and critical comments that will assist the National Academies of Sciences, Engineering, and Medicine in making each published report as sound as possible and to ensure that it meets the institutional standards for quality, objectivity, evidence, and responsiveness to the study charge. The review comments and draft manuscript remain confidential to protect the integrity of the deliberative process.

We thank the following individuals for their review of this report:

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Although the reviewers listed above provided many constructive comments and suggestions, they were not asked to endorse the conclusions or recommendations of this report nor did they see the final draft before its release. The review of this report was overseen by **CHRIS WHIPPLE (NAE),** ENVIRON (Retired), and **GEORGE APOSTOLAKIS (NAE),** Massachusetts Institute of Technology. They were responsible for making certain that an independent examination of this report was carried out in accordance with the standards of the National Academies and that all review comments were carefully considered. Responsibility for the final content rests entirely with the authoring committee and the National Academies.

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- The Center for Global Security Research (CGSR) at Lawrence Livermore National Laboratory for hosting the committee's July 2023 meeting: Brad Roberts (director, CGSR), Katie Thomas, Sandy Jackson, Michael Orozco, David Schoen, and Renee Travers.

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Contents

Summary

The United States and the world face serious threats to nuclear stability and peace, now and in the coming decades. Within the nuclear arena, U.S. policy makers will need to make strategic decisions related to nuclear risks to assist with long-term planning as well as responding in real time to unanticipated events. The occurrence of unanticipated nuclear events is expected to increase as more countries develop, expand, or field nuclear energy capability; more countries consider development of nuclear weapon capability and new nuclear weapon states emerge; and nuclear weapon states expand their nuclear arsenals. For the first time ever, a nuclear armed power is threatening the use of nuclear weapons during a large-scale conventional war and is occupying an operational civilian nuclear power plant in an ongoing conflict.

The United States' most recent National Security Strategy recognizes these expanded threats through a change in phrasing from *nuclear* deterrence to *integrated* deterrence (Biden, 2022). While the Biden administration is the first to use the term "integrated deterrence" in its national security documents, National Security Strategies and Nuclear Posture Reviews from previous administrations similarly highlighted the need to expand the scope of deterrence.[1] A common thread between the past and the current national security documents is that an integrated deterrence strategy is needed to address security environments that are complex and dynamic. Despite these complex and interconnected changes, the U.S. government assessments of nuclear risks are conducted within federal agencies that may be well-suited to address agency-specific needs but limit a wider consideration of factors contributing to overall risks connected to the use of nuclear weapons.

The Committee on Risk Analysis Methods for Nuclear War and Nuclear Terrorism was established and managed by the National Academies of Sciences, Medicine, and Engineering in response to a congressional mandate (P.L. 116-92, 2019) to independently explore U.S. government methods for assessing nuclear war and nuclear terrorism risks and how those assessments are used to develop strategy and policy. Key findings and conclusions of the committee are provided below.[2]

> FINDING 2-1: Risk analysis when conducted well, can provide a systematic and disciplined approach; illuminate threats, vulnerabilities, and consequences; and analyze complex interactive situations and dependencies among events. Good risk analysis has leadership guidance and support, informs leadership, and includes scenarios and exercises.

> FINDING 2-3: A well-performed risk analysis is decision focused, explicit about objectives, incorporates creative alternatives, addresses all relevant outcomes, characterizes uncertainties through development of scenarios and exploration of dependencies, addresses changes to risks over time, and supports transparent discovery and policy deliberation. These define, in part, fundamental principles of risk analysis.

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[1] For example, integrating elements of statecraft in support of national security strategy (including deterrence) appears at least as far back as the Clinton administration's National Security Strategy documents (Clinton, 1994). The George W. Bush administration's 2002 National Security Strategy also focused explicitly on leveraging advanced conventional weaponry to support nuclear deterrence missions, thereby reducing reliance on nuclear weaponry (Bush, 2002).

[2] The numbering of the findings and conclusions follows the numbering in the report and thus may not appear consecutively in the Summary.

Important details and key elements of each of these components are listed in Box 2-1 in Chapter 2.

CONCLUSION 2-1: The benefit of a well-performed risk analysis is that it prompts those requesting the analysis, who may have decision-making biases, to work in conjunction with those conducting the risk assessment to develop, for example, a systematic listing of potential outcomes; the pathways that can lead to those outcomes; and underlying assumptions, including correlations (dependencies) between different paths and outcomes.

There are many examples of risk analysis being used within the U.S. government to guide targeted questions related to components of nuclear terrorism risks or nuclear war risks, but few consider the wider-scoped questions of the overall risk of nuclear terrorism or overall risk of nuclear war.

Integrated deterrence expands the scope of deterrence to encompass multiple domains, including military and non-military (i.e., diplomatic, economic, technological, and information) domains, geographic regions, U.S. government agencies, and its allies and partners. It also intertwines conventional weapon and nuclear weapon use strategies.[3] The implementation of integrated deterrence will require coordination across a number of domains to enhance factors not previously emphasized within U.S. deterrence strategy.

CONCLUSION 3-1: Deterrence is an enduring strategic concept that needs constant rethinking and adaptations that are tailored to fit new and existing adversaries, changing contexts, and new circumstances. The U.S. government has acknowledged an expanded scope for deterrence as integrated deterrence, which seeks new ways to integrate contributions to deterrence across multiple domains (e.g., military and non-military organizations, U.S. agencies, and geographic regions). In this effort, the risk of deterrence failure leading to the use of nuclear weapons becomes one part of a larger set of risks. Due to the potentially catastrophic consequences of nuclear weapons' use, the U.S. government must recognize and prioritize the need to develop specific assessments of the risks of nuclear weapons use while implementing an integrated deterrence strategy.

Examples where risk analysis could contribute include the following: new strategic conditions with two or more adversaries with large nuclear arsenals; domestic and foreign terrorist organizations with possible connections between them; adversaries capable of creating strategic effects using cyber warfare; and adversaries with other weapons of mass destruction (i.e., biological, chemical) and adopting first-use doctrines.

The ability to maintain deterrence in peace and restore deterrence in war will be strongly influenced by thoughtful and well-done risk analysis that considers a wide range of possible outcomes—not simply the most probable or worst case. The United States has much that it can do to improve that ability.

[3] Integrated deterrence is "the seamless combination of capabilities to convince potential adversaries that the costs of their hostile activities outweigh their benefits" (Biden, 2022, p. 22). Also, see Box 1-1. With the expanded scope, there are multiple events that could signal a failure of integrated deterrence. For the purposes of this report and its focus on the risks associated with the use of nuclear weapons (which pose an existential threat), the committee chose to highlight integrated deterrence failures associated with the use of nuclear weapons at any level. The committee recognizes that some policy choices could include the use of nuclear weapons as a way to limit further escalation and that this may not be considered by some as a failure of deterrence.

1
Introduction Motivation and Context

The world is changing. We're at a significant inflection point in world history.

President Joseph Biden, Jr.
U.S. Coast Guard Academy's 140th Commencement Exercises, May 19, 2021

The United States and the world face serious threats to nuclear stability and peace, now and in the coming decades, and U.S. policy makers will need to make strategic decisions to both assist with long-term planning and react to unanticipated rapid changes in the nuclear arena. Examples include the following: the current war in Ukraine, nuclear developments in the Middle East and Northeast Asia over the years, potential nuclear proliferation by countries friendly to the United States, and the past decades' security crises in South Asia. The threat of nuclear war erupting from non-nuclear conflict is not just a Cold War or immediate post-Cold War relic, but a matter of current and even urgent concern.

Despite the Nuclear Nonproliferation Treaty, nuclear arsenals are an openly documented reality in South and Northeast Asia; military conflicts among nuclear-armed Pakistan, India, and China have been ongoing since the 1990s;[1] and Iran's stockpile of enriched uranium continues to increase (IAEA, 2022). Russian troops' unprecedented occupation of a commercial nuclear power plant in Ukraine presents yet another form of nuclear danger as of 2023 (Granholm, 2023), as does the documented interest in nuclear-explosive technologies expressed by certain terrorist groups since at least 2000.

At the same time, regional conflicts between countries with ties to great nuclear powers (United States, Russia, and China) are on the rise including Iran and Israel, India and Pakistan, and China and Taiwan.[2] These many developments led to a declaratory shift in U.S. strategy from *nuclear* deterrence to *integrated* deterrence as described in the publicly available National Security Strategy and National Defense Strategy (Biden, 2022; DoD, 2022; see Box 1-1).[3] Nuclear terrorism threats are also evolving as nuclear proliferation and an anticipated expanded use of advanced nuclear reactors among nation states increases opportunities for loss of material control and insider threats or possibilities of a nuclear state assisting terrorist groups. These shifts, and the increased U.S. policy focus on near-peer competition, are also present in the publicly available comments related to the National Security Memo (NSM) "U.S. Strategy for Countering WMD and Securing Nuclear and Radiological Materials."[4] Approaches to assessing risks of both nuclear war and nuclear terrorism to guide policy decisions should be able to accommodate and adapt to these shifts.

[1] There have been numerous crises and military clashes and one war (Kargil War in 1999).

[2] Great powers flexing their strength and regional conflicts of smaller states with great power allegiances are reminiscent of 1914 leading up to World War I. The difference between today and 1914 is that the great powers possess nuclear arsenals.

[3] Previous administrations have similarly highlighted the need to expand the scope of deterrence across diplomatic, military and non-military (technological) domains, the U.S. interagency, spectrum of deterrence failures, and allies and partners—as noted in their National Security Strategies and Nuclear Posture Reviews (Clinton, 1994; Bush, 2002).

[4] See the NSM-19 Fact Sheet, available at https://www.whitehouse.gov/briefing-room/statements-releases/2023/03/02/fact-sheet-president-biden-signs-national-security-memorandum-to-counter-weapons-of-mass-destruction-terrorism-and-advance-nuclear-and-radioactive-material-security.

BOX 1-1
Integrated Deterrence Defined

Integrated deterrence is a term introduced in the Biden administration's security strategy documents, expanding and broadening deterrence while still encompassing nuclear deterrence as a key component of national defense.[a] This expanded definition of deterrence also intertwines conventional weapon and nuclear weapon use and strategies. As described in the Biden administration's National Security Strategy, integrated deterrence requires coordination across a number of domains (Biden, 2022, p. 22):

- Integration across domains—military (land, air, maritime, cyber, and space) and non-military (economic, technological, and information)
- Integration across regions—understanding that our competitors combine expansive ambitions with growing capabilities to threaten U.S. interests in key regions and in the homeland.
- Integration across the spectrum of conflict—to prevent competitors from altering the status quo in ways that harm our vital interests while hovering below the threshold of armed conflict.
- Integration across the U.S. government—to leverage the full array of American advantages, from diplomacy, intelligence, and economic tools to security assistance and force posture decisions.
- Integration with allies and partners—through investments in interoperability and joint capability development, cooperative posture planning, and coordinated diplomatic and economic approaches.

[a] Integrated deterrence is first formally defined in the 2022 unclassified National Defense Strategy and its associated Nuclear Posture Review, but similar concepts were highlighted in Nuclear Posture Reviews of previous administrations.

To navigate the coming decades, the U.S. government leaders will need to rely on nuclear security and deterrence experts who will use a variety of methods to broadly assess the short- and long-term risks of conflict, anticipate adversary actions that could lead to nuclear war or terrorism, and understand the potential impact of U.S. responses to those actions. A key objective of risk analysis applied to nuclear war and nuclear terrorism is to avoid the catastrophic consequences of nuclear events, the challenge being to help decision makers identify, understand, and mitigate the impacts of a wide range of scenarios. Risk analysis, done well, provides important tools and results that can help address this challenge systematically, thereby offering decision makers a wider array of options and choices and potentially reducing the chances of nuclear destruction. It could address an issue identified by Thomas Schelling in his foreword to Roberta Wohlstetter's *Pearl Harbor: Warning and Decision* (Wohlstetter, 1962):

> There is a tendency in our planning to confuse the unfamiliar with the improbable. The contingency we have not considered seriously looks strange; what looks strange is thought improbable; what is improbable need not be considered seriously.

BACKGROUND AND CHARGE FOR THE STUDY

The committee was established and managed by the National Academies of Sciences, Engineering, and Medicine, in response to a congressional mandate (P.L. 116-92, 2019). Biographies for committee members are listed in Appendix A. Congress tasked the Department of Defense to contract with the National Academies to independently explore U.S. government methods for assessing nuclear war and nuclear terrorism risks and how those assessments are used to develop strategy and policy. The committee's statement of task is reprinted in Box 1-2.

The committee's work was conducted in two phases, without congressional oversight. Phase I produced an unclassified report (NASEM, 2023) focused on Tasks 1–3 of the statement of task and relied on unclassified, publicly available information. Specifically, within the Phase I report, Chapters 2 and 4, outline classes of scenarios and threats leading to nuclear war or nuclear terrorism; Chapter 3 explores the prior literature, and Chapters 5 and 6 discuss risk analysis including qualitative and quantitative methods and their applications to the nuclear risks problem set. The Phase I report laid the groundwork for Phase II by outlining methods that are used in risk assessment for a variety of applications. In Phase II, with access to classified briefings and reports up to the Secret level, the committee focused on Tasks 4 and 5 by exploring the use of risk methods to estimate the risks of nuclear war and nuclear terrorism and how the results are used to guide nuclear strategy. The committee also reviewed its Phase I responses to Tasks 1–3, in light of the additional classified information. This report is an abbreviated version of a longer report determined to contain Controlled Unclassified Information (CUI).

CONCLUSION 1-1: The Phase I report focused on Tasks 1–3 of the committee's tasking. Although it contained no findings or recommendations, it produced a set of conclusions. Those conclusions were further supported by information gathered by the committee during Phase II (the classified phase), and the committee determined that the Phase I conclusions required no changes.

BOX 1-2
Statement of Task

The National Academies of Sciences, Engineering, and Medicine will convene an ad hoc committee of experts to examine whether a risk assessment framework is applicable to determining the potential risks of nuclear terrorism and nuclear war; and to examine assumptions in nuclear policy and doctrine and their implications on national security. During this examination, the committee will undertake the following:

1. Identify risks associated with nuclear terrorism and nuclear war;
2. Explore the prior literature relevant to assessing risks of nuclear terrorism and nuclear war;
3. Assess the role that quantitative and nonquantitative analytical methods can play in estimating such risks, including the limitations of such analysis;
4. Identify and examine the assumptions about nuclear risks that underlie the national security strategy of the United States; and
5. Describe the consequences or impacts of the methods and assumptions that have been, are, or could be used in developing the nuclear security strategy of the United States.

The committee will issue an unclassified Phase I report which may include findings and recommendations regarding the use of analytical methods to assess the risks of nuclear terrorism and nuclear war.

At the conclusion of the study, the committee will issue a final Phase II report that expands upon the use of analytical methods to assess the risks of nuclear terrorism and nuclear war and the role such approaches may play in U.S. security strategy. This final report may include findings and recommendations supported by classified information.

Risks of nuclear war have been affected by Russia's 2022 invasion of Ukraine. In Phase II, the committee considered how U.S. strategic deterrence assessment of nuclear war risks have changed—or need to change—in response to the evolving threats of Russia's invasion of Ukraine,[5] as well as the emergence of two near-peer adversaries (Russia and China) and a nuclear-armed North Korea (USSTRATCOM, 2021).

This report is intended to provide an overview, guidance, and advice to the U.S. government on the development of risk assessments for nuclear war and nuclear terrorism in changing environments. The report will be equally relevant to the federal agencies and congressional committees who play a critical role in guiding and contributing to nuclear strategy and policy. In responding to the committee's statement of task and in the context of this historical moment, the aim of this report is to identify how risk analysis tools are useful and can (1) improve the development of strategy for nuclear deterrence in the context of integrated deterrence, and (2) support decision making for countering nuclear terrorism.

INTERPRETATION OF THE STATEMENT OF TASK

The committee was briefed on and investigated the methods used by U.S. government and contractor analysts to assess risks of nuclear war and nuclear terrorism as well as the context and breadth of these analyses. It did not perform a risk assessment of nuclear war or nuclear terrorism, nor estimate those risks, but it did consider how risk assessments are conducted—by whom, on whose request, and with what assumptions—and how the assessments are used to guide strategy development.

In Phase I, the role of risk analyses (Task 2) was explored by considering and identifying approaches for assessing both the overall risk as well as more focused risks of nuclear war and nuclear terrorism. These focused risks, or components of the overall risk, include programmatic or technological risk such as estimating the reliability of a particular country's nuclear stockpile; or determining the detection probability of a particular model of radiation detector at Ports of Entry. In Phase II, with access to classified information and discussions with U.S. analysts and decision makers, the committee was able to more deeply explore the roles that analytical methods play in estimating overall and more focused components of nuclear risks, the benefits of the risk analysis process, and the interface between risk analysis output and strategy development (Tasks 4 and 5).

Finally, the committee interpreted its statement of task as focusing on the methods of risks and strategies involving nuclear conflicts and risks of nuclear terrorist attacks against the United States. Nevertheless, it recognizes that a nuclear war or terrorist act anywhere would have profound ramifications everywhere around the world, the United States included.

ORGANIZATION OF THE REPORT

This report contains four chapters and three appendixes. Chapter 1, this chapter, contains one conclusion. Chapter 2, "Risk Analysis," outlines what risk analysis is, what it can do, and what constitutes good risk analysis (Box 2-1). Chapter 2 contains five findings and two conclusions. Chapter 3, "Development of Risk-Informed Strategies," explores the interface between risk assessment and decision making in the context of changing U.S. deterrence strategy and countering weapons of mass destruction strategy guidance; one conclusion is made. Examples are also presented of how a new risk analysis capability to analyze the specific risks of deterrence failure leading to the use of nuclear weapons (a subset of the wider set of risks leading to integrated deterrence failure) might be implemented. Chapter 4 provides a short conclusion.

[5] At the time of the Russian invasion into Ukraine (February 2022), the Phase I report had already entered the National Academies review process so the Phase I committee did not have an opportunity to collect information on the invasion's impact on risk methods for assessing nuclear war and nuclear terrorism within the U.S. government, as noted in the Phase I Preface.

Appendix A contains the biographies of Phase II committee members, consultants, and staff. Appendix B is the set of questions developed by the committee to guide the content of presentations for invited speakers and briefers and for document requests to U.S. government agencies. Appendix C comprises the list of presenters and briefers during Phase II data collection.

As the United States continues to implement the expanded scope of integrated deterrence, there are multiple events that could signal deterrence failure. For the purposes of this report and its focus on the risks associated with the use of nuclear weapons (which pose an existential threat), the committee chose to highlight integrated deterrence failures associated with the use of nuclear weapons at any level. The committee recognizes that some policy choices could include the use of nuclear weapons as a way to limit further escalation and that this may not be considered by some as a failure of deterrence.

2
Risk Analysis

Risk analysis aims to systematically identify the pathways from present circumstances to future outcomes, and the likelihood of negative consequences occurring. To be reliable, the analysis must include a realistic—and in principle complete—description of all the ways that the current state can lead to those future outcomes of concern. Such an analysis requires consideration of future outcomes, some of which may be hypothetical. It is especially difficult for situations for which there is little or no direct experience—nuclear war and nuclear terrorism being cases in point.

Risk analysis, performed well, encourages participation between those requesting the analysis and those conducting it. The process also helps to inform leadership of the decisions, options, and timelines that can be expected if a harmful event occurs. The principles of a well-conducted risk analysis are outlined in Box 2-1. The risk analysis results can aid in prioritization of different decision outcomes; for example, identifying pathways that are most likely to be more harmful, which therefore must be avoided or mitigated even if at great effort. Additionally, identifying the pathways provides the basis for training and preparation to avoid, minimize, or mitigate the failure modes.

Box 2-1 highlights the importance of characterizing and assessing uncertainties in a well-done risk analysis using scenarios to both span potential outcomes and understand dependencies. One of the challenges in making decisions related to avoiding nuclear weapons use (and its risks) or nuclear terrorism is due to the sparsity of direct experience or statistical evidence and the corresponding large uncertainties.

In some risk analyses, relevant statistical data bases exist from which one can calculate probabilities (i.e., frequencies of occurrence) for use in the risk assessment. When relevant statistical samples and probabilities based on frequencies in such samples are limited, Bayesian approaches that utilize conditional probabilities can aid in developing risk analysis. Even if data samples exist, Bayesian approaches can help the risk analyst account for additional information that is known about the system (e.g., information gathered from expert opinions, models, and surrogate data from similar situations) and also reflect aspects of the scenario that may evolve with time (e.g., changes in the adversary, technology, or operations). The probability of a scenario can then be computed as a series of conditional probabilities reflecting the scenario description (see NASEM, 2023, Chapters 5 and 6). That assessment captures the dependencies among events, through conditional probabilities.

The same Bayesian logic can be used to assess the analyst's beliefs about a future risk given new available information, which could include false positives (i.e., a "false alarm") or false negatives (i.e., a missed warning or signal). Both types of errors have to be included in the updating of the probability to assess the value of that information as the possible improvements of the decision. This computation allows accounting for the uncertainties both in the events a priori, and in the information, which can be correct but can also include false positives or simply not include signals when it should (false negatives). That logic allows assessing the value and validity of information of a message, which may allow improving a decision involving uncertain events.

BOX 2-1
Fundamental Principles of Risk Analysis

Risk analysis encompasses a wide range of activities and methods. According to the Society for Risk Analysis (SRA), risk analysis includes "risk assessment, risk characterization, risk perception, risk communication, risk management, risk governance, and policy relating to risk, in the context of risks of concern to individuals, to public and private-sector organizations, and to society at a local, regional, national, or global level."[a] Risk analyses that are high quality and trustworthy are based on the fundamental principles of risk analysis.

Risk analysis of nuclear war is typically conducted at the global and regional levels, considering conflict among two or more nations. Risk analysis of nuclear terrorism typically considers: threats from the use of nuclear and radiological weapons; global actors; global, national, and local vulnerabilities; and national, regional, and local consequences. In principle, both will also consider the intent, capabilities, and beliefs of adversaries. Based on SRA principles, committee-member expertise, and testimony provided to the committee, the committee identified the following risk-analysis principles tailored to the requirements and challenges of analyzing the risks of nuclear war and the risks of nuclear terrorism. The short list summarizes components of a high-quality risk analysis.

1. *Identify the potential risk management decision(s).* Risk analysts need to understand the strategy, policy, funding, system acquisition, or system operational decision(s) that the risk analysis could inform, so that the risk analysis is scoped to meet the needs of the decision makers and stakeholders. This improves the relevance, effectiveness, and efficiency of the risk analysis results. Some risk analyses could be performed periodically to assess potential risks and inform budget allocations (e.g., risk of nuclear terrorism). Other risk analyses may be performed to inform a particular decision (e.g., a change in operational readiness of nuclear forces).
2. *Specify the decision objectives.* Once the type of decision is determined, the objectives of the decision makers and stakeholders need to be understood by the risk analysts. This can be challenging when policy preferences are not clear or evolving. Obtaining guidance and support from decision makers for analysis can also be challenging. Risk analysts may also need to consider the potential objectives of allies and adversaries, which can be difficult to estimate.
3. *Identify creative, practical alternatives.* For decisions involving significant risks, policy makers need a wide set of possible alternatives to remove, avoid, or mitigate the risks, as possible within time, resource, and capability constraints. Risk analysts should seek to identify these alternatives and include them in their risk analyses. Analysts also should continue to search for better alternatives at all stages of risk analysis.
4. *Define the potential outcomes.* Once the decision and the decision objectives are defined, risk analysts need to identify and assess a broad range of outcomes that reflect the concerns of interested and affected stakeholders, and the relative priorities of those different outcomes. Failure to adequately reflect the values of those making (and affected by) decisions can bias analysis results due to omission of outcomes, or mischaracterization of the priorities of outcomes. The characterization of outcomes is especially challenging for the risks of nuclear war and nuclear terrorism.
5. *Assess the relevant uncertainties.* There are large uncertainties in the available information related to risks of nuclear terrorism and nuclear war including adversary objectives and capabilities (nation-state and terrorist), potential attack scenarios, adversary actions and reactions, the performance of existing systems and new technologies for offensive and defensive purposes, the efficacy of security measures (including contributions to deterrence), and the short- and long-term outcomes of the use of nuclear and radiological weapons in a nuclear war or a terrorist attack. The identification and quantitative or qualitative assessment of these uncertainties is an essential task in risk analysis.
    a. *Scenarios.* Scenarios are a valuable tool for identifying and analyzing uncertainties. Scenarios allow assessment of risk across a wide and meaningful set of future conditions over which events might occur. Failure to do so can lead to

errors through omission of factors that affect adversary decisions, adversary capabilities, or the effectiveness of security measures. Scenarios can be made extremely complex by adding details that may not be fully relevant to the decision objectives, to the point at which their likelihood becomes very small with the addition of each detail or component. Scenario specificity is a balancing act—analysts have to balance identifying groups of scenarios in a description that is simple enough that it can be analyzed and, at the same time, includes all the essential components that will make the results relevant.

b. *Dependencies.* Uncertainty analysis should identify and assess the dependencies among the elements of the scenarios, decisions, adversary actions, and outcomes that could happen in each scenario. These dependencies need to be identified and modeled or assessed—ideally quantitatively. In this case, the probability assigned to an event is conditioned on other dependent events, such as previous decisions of the United States and its adversaries. For example, reducing U.S. vulnerabilities can affect adversary actions.

6. *Include dynamics.* Time is an important consideration in nuclear risk analysis. Risk analysis must be dynamic to reflect how adversaries, scenarios, technologies, options, outcomes, and preferences may change in the future and it must include a time horizon because, for example, risks of nuclear war and nuclear terrorism are not static.
7. *Provide transparent analyses.* Risk analysts need to present their analysis in a manner that enables inspection and independent review of their assumptions, scenarios, uncertainties, models, outcomes, and results by decision makers, stakeholders, and peer reviewers. The analysis, data, and results need to be clear, traceable, and understandable. This will require significant effort above and beyond simply conducting the analysis, but it is becoming the standard practice for high-quality research.

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[a] See the Society for Risk Analysis website (sra.org), accessed July 14, 2023.

The 2013 report of the Institute of Medicine, *Environmental Decisions in the Face of Uncertainty*, identified types of uncertainties associated with risk analysis to aid decision making within the Environmental Protection Agency. The report suggests that scenario development be used for events for which little or nothing is known about the event's impact or likelihood to aid decision makers and risk analysts (IOM, 2013). An example of one such a situation is climate change. The Intergovernmental Panel on Climate Change has developed and regularly updates a set of possible scenarios. The aim of the scenarios is not to predict the future but to assess the uncertainties linked to possible climate and socioeconomic futures, which can inform decisions (IPCC, 2022).

FINDING 2-1: Risk analysis, when conducted well, can provide a systematic and disciplined approach; illuminate threats, vulnerabilities, and consequences; and analyze complex interactive situations and dependencies among events. Good risk analysis has leadership guidance and support, informs leadership, and includes scenarios and exercises.

FINDING 2-2: Those in charge of developing policy or strategy ought to be made aware of how risk methods could improve options to mitigate risks of nuclear weapons use or nuclear terrorist attacks especially at a time when those risks are rapidly evolving.

FINDING 2-3: A well-performed risk analysis is decision focused, explicit about objectives, incorporates creative alternatives, addresses relevant outcomes, characterizes uncertainties through development of scenarios and exploration of dependencies, addresses changes to risks over time, and supports transparent discovery and policy deliberation. These define, in part, fundamental principles of risk analysis.

Important details of each of these components are listed in Box 2-1.

CONCLUSION 2-1: The benefit of a well-performed risk analysis is that it prompts those requesting the analysis, who may have decision-making biases, to work in conjunction with those conducting the risk assessment to develop, for example, a systematic listing of potential outcomes; the pathways that can lead to those outcomes; and underlying assumptions, including correlations (dependencies) between different paths and outcomes.

U.S. GOVERNMENT RISK ANALYSIS METHODS

The committee collected information relevant to its tasking in classified meetings held over 7 months. A full list of the presenters and their affiliations can be found in Appendix C. Throughout its information collection efforts, the committee searched for examples of risk assessment methods (Who is doing what?) and how their results were used to develop strategy and guide policy and decisions. Three specific risk analysis efforts are described in this chapter.

Differences in Nuclear War and Nuclear Terrorism Risks

Nuclear war and nuclear terrorism risk methods are distinct in important ways. The risk of nuclear war is often assessed by considering nuclear armed adversary decision calculus, while the risk of nuclear terrorism is most often focused on the availability of nuclear materials that might be used by a non-state actor or state-sponsored terrorist group to obtain a nuclear device or to construct an improvised nuclear device or a radiological dispersal device.[6] Two forms of deterrence come into play for both war and terrorism: the power to hurt (i.e., retaliation) and the power to deny (i.e., preventing an adversary from achieving objectives through either defenses or prevention of their capabilities).

For policy analysts and senior decision makers, the threats posed by other nation states with nuclear weapons often drives decision making in documents such as the Nuclear Posture Review. The Obama administration's commitment to modernizing the U.S. nuclear deterrent forces accompanying Senate ratification of the 2010 New START Treaty is a good example. Estimating the potential threat posed by a nuclear armed adversary's capabilities is as critical as examining the impact of U.S. responses to that threat, and identifying military threats and diplomatic assurances that could lead to avoiding or ending a nuclear conflict on acceptable terms to reduce further escalation.

In contrast, decision makers in the nuclear terrorism arena are often more focused on nuclear materials attractiveness, availability, and quantity (e.g., based on assessments of the effectiveness of security measures to protect nuclear materials). These assessments can guide considerations of where to focus U.S. non-proliferation and nuclear material security assistance programs and dollars. Furthermore, the role of a nuclear nation-state actor distinguishes programmatic decisions in the nuclear terrorism field from those facing decision makers concerned about nuclear deterrence and nuclear war.

FINDING 2-4: To deter nuclear terrorism, the United States has focused on minimizing access to nuclear materials (i.e., the power to deny access), but state-sponsored terrorism can also be deterred by the power to hurt (i.e., threat of punishment once attributed). Nuclear war deterrence is broader and includes deterrence by denial of adversary objectives through U.S. resilience and the threat of a U.S. response that imposes expected costs that are clearly higher than expected benefits of nuclear use (i.e., the power to deny and destroy).

[6] The Phase I report addressed the scenarios (Chapter 2), history and literature of risk assessment (Chapter 3), and the use of risk assessment for nuclear war and nuclear terrorism (Chapter 4). These three chapters also highlight the differences between the risk of nuclear war and nuclear terrorism.

EXAMPLES OF RISK ANALYSIS METHODS WITHIN THE U.S. GOVERNMENT

The committee highlights three methods for assessing nuclear risks or risks associated with nuclear use that are being conducted within the U.S. government.

Defense Threat Reduction Agency Nuclear Consequence Models

Consequence is one part of a traditional risk equation. The Defense Threat Reduction Agency (DTRA) maintains the Department of Defense's (DoD's) nuclear war consequence models, which are used across DoD and therefore have a large impact on DoD's strategic thinking on nuclear war. In the committee's Phase I report, the committee outlined the effects of a nuclear explosion by its immediate, near-, and long-term effects (NASEM, 2023):

> The Immediate effects of a nuclear explosion include an intense burst of gamma and neutron radiation; a fireball (anything inside the fireball is likely to be totally consumed); an intense, blinding flash and a pulse of thermal radiation (causing burns and igniting fires); a powerful blast wave, accompanied by intense winds; and an intense electromagnetic pulse (localized for blasts within the atmosphere, but more far-reaching for blasts in space). (p. 52)
>
> Near- and long-term effects are wide reaching. In the near term (roughly, 1 hour to 1 week after the event), widespread evacuations and grid instability are possible along with initial radiation effects on humans. In the long term (weeks to several months or years after the event), effects include social and economic unrest, political and governance crises, health effects, infrastructure failures, negative environmental and climate effects, migration, and psychological distress. (p. 52)
>
> Updating our Cold War understanding of blast damage in a modern city is another important area of research. The bombings of Hiroshima and Nagasaki demonstrated that the area of glass breakage is nearly 16 times greater than the area of significant structural damage. Injury from broken glass has not previously been well modeled, however, because cold war planners generally considered it not of military significance. (p. 54)
>
> [E]arly studies show that some researchers (and funders) recognized the importance of and were beginning to explore the social and psychological effects of nuclear war. It is noteworthy and disturbing that there has been so little attention to further deepening understanding of these vital impacts since 1986. (p.55)

In its briefing to this committee, DTRA confirmed that their nuclear effects categorization and scope is similar.

> FINDING 2-5: Within DoD, DTRA provides estimates of the impact of nuclear weapons. The consequence assessment is focused on prompt effects and military objectives. This results in a partial accounting of the consequences leading to a limited understanding of the breadth of the outcomes.
>
> *CONCLUSION 2-2: Current modeling by DoD's DTRA of the consequences of nuclear explosions resulting from strategic deterrence failure are limited to prompt military effects, especially detonation (blast) and some fallout effects, and does not extend to broader and longer-term effects. This information further supports this committee's Phase I Conclusion 4-1, that there is a need to improve the understanding of the physical effects of nuclear weapons (e.g., fires, damage in modern urban environments, electromagnetic pulse effects, and climatic effects, such as nuclear winter), as well as the assessment and estimation of psychological, societal, and political consequences of nuclear weapons use.*

Risk of Strategic Deterrence Failure

U.S. Strategic Command (USSTRATCOM) Risk of Strategic Deterrence Failure (RoSDF) is a recently developed, formalized, qualitative tool that assesses the estimated impact of diplomatic, informational, military, and economic factors on the risk of deterrence failure. Within RoSDF, "adversary decision calculus" is a method cited to assess an adversary's goals, psychology, cultural perspective, information, and reasoning (USSTRATCOM, 2021). Adversary decision calculus is within USSTRATCOM's RoSDF as well as by the Joint Staff (J5). The method can guide U.S. actions to maximize deterrence; adversary's responses are closely monitored after actions are taken by the United States such as commencing military exercises, verbal statements made by U.S. officials, or alerting U.S. forces.

However, adversary decision calculus has important weaknesses. Some of these were discussed in the Phase I report (NASEM, 2023). One basic weakness is the contrast with scenario-based methods that are highlighted earlier in this chapter. Scenario-based methods force more attention to interactive behavior and other dependencies that influence potential outcomes.

Risk of Nuclear and Radiological Terrorism

The Department of Homeland Security's (DHS's) Science and Technology Directorate (S&T) is responsible for developing and maintaining the capability to perform terrorism risk assessments of weapons of mass destruction tailored to a variety of different users (DHS, 2021). DHS uses probabilistic risk assessment methodology to assess risk that uses a set of scenarios with data derived and modeled probabilities and consequences. Risk assessments are scaled to user requirements and can be used to address components of overall risk, or they can be used to assess the overall risks of a nuclear, radiological, chemical, or biological attack on the United States.

Another key aspect of DHS's risk assessment effort is its interface with the consumers of these assessments:

> Development of the risk assessments has been an ongoing, community-driven process so as to ensure that the methodology and resultant outputs adequately address the needs of the Homeland Security Enterprise (HSE) and interagency stakeholders. On a regular basis, S&T [and CWMD] meets with other DHS components and interagency partners to gather requirements for risk assessments and to ensure that the results are vetted by the appropriate experts. (DHS, 2021, p. 2)

This is consistent with a well-conducted risk assessment (see Box 2-1).[7]

Intelligence-Informed Leadership Judgment—or Intel-Driven Assessments

Intelligence assessments follow strict analysis and reporting guidelines (Grabo, 2002; DIA, 2009) to characterize and understand threats to the United States. For long-standing intelligence oversight reasons, the Intelligence Community (IC) does not collect information on or analyze interactions with U.S. plans and choices, nor does the IC typically assess the consequences or vulnerabilities to the United States or its interests. However, those developing strategy may use intelligence reports to develop their own "intel-driven assessments" or "intelligence-informed leadership judgment" (Roberts, 2022).

[7] The committee had no opportunity to validate this claim.

3
Development of Risk-Informed Strategies

Decision makers must often act with incomplete information – both for real-time, quick decisions to respond to crises as well as the slower paced (but no less important) development of a strategy that may involve future tactical decisions. Both situations require a broad look at a variety of threats and outcomes weighed against resources, policies, and administration priorities.

A key component of the committee's tasking was to explore the interface between risk assessment and the development of strategy (Tasks 4 and 5, see Box 1-2). The committee heard from a variety of U.S. government decision and policy makers who were asked about how they utilize risk assessments related to nuclear war and nuclear terrorism, what methods they used to guide decisions, and the assumptions they made in developing nuclear security strategy for the United States.

Decisions that rely on intelligence and leadership judgment can be made quickly, so are well-suited to address real-time issues. However, they are susceptible to bias and group think (see "Challenges to the Elicitation and Use of Expert Opinion" and the references therein in the Phase I report [NASEM, 2023]) and often the number of experts is limited so the scope of possible outcomes is also limited. These known decision-making biases can be mitigated by risk analysis.

IMPLEMENTING INTEGRATED DETERRENCE

Integrated deterrence, as defined in Box 1-1, expands the scope of deterrence across domains, regions, types of conflict, and the U.S. government and its allies and partners. With this expanded scope, it is important to not lose sight of nuclear deterrence in particular. Nuclear war is a threat to the world as we know it. President Reagan's famous 1982 quote, "Nuclear war cannot be won and must never be fought," has been reiterated by the leaders of the five Nuclear Weapon States as recently as January 2022 (White House, 2022). Yet, President Putin's invasion of Ukraine and his threats to use nuclear weapons have highlighted the need for a wider variety of assessments of nuclear weapon use and its consequences.

The implementation of an expanded scope of deterrence provides an opportunity for the United States to address what some have characterized as a widening gap in deterrence strategy expertise between the United States and its adversaries. Brad Roberts's *On Theories of Victory, Red and Blue* (Roberts, 2020) highlights the gap in strategy development over the past few decades and cites a number of reports supporting this claim. The 2018 National Defense Strategy Commission "Providing for the Common Defense" (NDSC, 2018, p. 1-2, paraphrased) emphasized the need for the United States to develop innovative operational approaches to overcome difficult operational challenges and a lack of analytical capability, expertise, and processes to guide DoD strategy. General Joseph Dunford noted that the United States is behind in adapting to the changed character of war[1] and Peter Roberts, director of the Royal United Services Institute in London has claimed that adversaries of the United Kingdom and the United States have reimagined warfare and conflict (Roberts, 2017, pp. 14 and 23).

[1] Remarks at the National Defense University Graduation Ceremony, Fort McNair, Washington, DC (June 10, 2016).

CONCLUSION 3-1: Deterrence is an enduring strategic concept that needs constant rethinking and adaptations that are tailored to fit new and existing adversaries, changing contexts, and new circumstances. The U.S. government has acknowledged an expanded scope for deterrence as integrated deterrence which seeks new ways to integrate contributions to deterrence across multiple domains (e.g., military and non-military organizations, U.S. agencies, and geographic regions). In this effort, the risk of deterrence failure leading to the use of nuclear weapons becomes one part of a larger set of risks. Due to the potentially catastrophic consequences of nuclear weapons' use, the U.S. government must recognize and prioritize the need to develop specific assessments of the risks of nuclear weapons use while implementing an integrated deterrence strategy.

As noted in Conclusion 2-1, risk analysis can provide a systematic way to widen the lens when considering options. For example, an existing, well-constructed risk analysis capability can assist both in making quick decisions and in the development of long-term strategy. However, it requires active engagement of all sources of relevant information across government, industry, and academia. It also benefits from the attention and participation of decision makers throughout the process. DHS has a capability for assessing quantitative risks of nuclear terrorism and a partial qualitative nuclear war risk analysis capability exists in USSTRATCOM's RoSDF but it is focused on military objectives.

Much more can be done, however, especially to capture a wider range of consequences and vulnerabilities. For example, within the U.S. government, multiple federal agencies that could contribute to an integrated-deterrence risk assessment of nuclear war are shown in Table 3-1 (this table is not intended to be exhaustive). Other new and diverse strategic threats could also be considered, including chemical, biological, and cyber weapons, and proliferation of nuclear weapons.

For deterrence strategy to become integrated across its multiple domains, an interagency integrator with access to federal agency capabilities could be useful to make best use of the information and responsibilities across the government.[2] Examples of groups formed by the President to address high-priority topics include interagency working groups, presidential task forces, and ad hoc groups (i.e., tiger teams).[3] The advantage of declared interagency efforts is that it signals the importance of an issue and its priority within an administration. It also outlines the organization of the group and allows outside expert participation (e.g., academia, university affiliated research centers, think tanks, private sector, and industry) and access to federal agency capabilities and resources such as federal agency experts, including parts of DoD, Department of Energy National Laboratories, and other federally funded research and development organizations. A recent example is the effort that outlined the U.S. Strategy for Countering WMD and Securing Nuclear and Radiological Materials.[4] Several concepts that would contribute to establishing a risk analysis capability are listed in Box 3-1.

The committee identified a set of potential activities or actions that could expand the use of risk analysis to guide the implementation and management of integrated deterrence, especially as it relates to nuclear war. One option that could provide a focus on risks of nuclear weapons use in the context of integrated deterrence is to reinstate or recreate a similar function to the National Intelligence Officer for Warning. Yet another idea was to create an annual or biannual federally hosted workshop or meeting to share nuclear risk methods and results across the U.S. government. This could increase awareness of others working in the same space, the sharing of capabilities, and improve integration.

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[2] Currently, DoD is leading the implementation of the integrated deterrence strategy.

[3] A presidential task force or White House task force is a board of advisors appointed by the President of the United States whose main purpose is to enact policies in relation to responding to either national emergencies, crises, or general policy initiatives.

[4] See the NSM-19 Fact Sheet, available at https://www.whitehouse.gov/briefing-room/statements-releases/2023/03/02/fact-sheet-president-biden-signs-national-security-memorandum-to-counter-weapons-of-mass-destruction-terrorism-and-advance-nuclear-and-radioactive-material-security.

TABLE 3-1 Examples of Federal Agencies with Relevant Expertise or Authority

Federal Agency	Expertise or Authority
Department of Agriculture	Food resources
Department of Commerce	Supply chains
National Oceanic and Atmospheric Administration	Environmental effects
Department of Defense	
Defense Intelligence Agency	Intelligence
Defense Threat Reduction Agency	Military consequences
U.S. Strategic Command and Geographical Combatant Commands	Nuclear strategy and planning including risk analysis, nuclear weapons, and nuclear security
Office of the Secretary of Defense Policy	Nuclear policy
Department of Energy	Energy resources and energy security
National Nuclear Security Administration	Nuclear weapons and nuclear security
Office of Science within Biological and Environmental Research	Biological and environmental effects
Department of Health and Human Services	Public health
Department of Homeland Security	Homeland effects, response
Cybersecurity and Infrastructure Security Agency	Cyber threats and resilience; infrastructure security and resilience
Federal Emergency Management Agency	Preparedness, response, recovery, and resilience
Science and Technology Directorate	Threats, consequences modeling
Countering Weapons of Mass Destruction	Nuclear and radiological material detection and incident response
Customs and Border Protection and U.S. Coast Guard	Securing containerized supply chains and critical infrastructure
Department of the Interior	Water, mineral, fossil fuel resources
Department of Justice	Legal effects
Federal Bureau of Investigation	Illegal activities in the homeland; material trafficking; transnational terrorism and criminal networks
Department of State	International relations
Department of Transportation	Transportation, supply chains
Federal Aviation Administration	Air traffic
Department of the Treasury	Economic consequences, mitigation
Environmental Protection Agency	Environmental effects
Federal Communications Commission	Communication effects, response
Federal Reserve	Banking
Intelligence agencies, including the Central Intelligence Agency, the Office of the Director of National Intelligence, and the National Counterproliferation Center	Intelligence threat analysis and adversary capabilities
National Aeronautics and Space Administration	Space effects
National Science Foundation within the National Center for Atmospheric Research	Atmospheric effects
Nuclear Regulatory Commission	Nuclear-environmental effects, response to threats to commercial reactors

BOX 3-1
Concepts for an Interagency Nuclear Risk Analysis Capability to Guide Decisions

The National Security Advisor is in a position to coordinate and integrate the required expertise from across the entire government in responding to an imminent nuclear crisis or planning for future crises by the establishment of an interagency integrated deterrence risk analysis capability. The capability must be supported by technically based and enduring expertise such as those that reside within the federal agencies as well as outside experts (see main text). Examples of agencies with relevant expertise are listed in Table 3-1. This capability would likely be invisible at most times to agency and administration decision makers.

The capability would not lie dormant, however, as it would need to:

1. Identify possible scenarios leading to the use of nuclear weapons as threats and capabilities evolve;
2. Identify the necessary consequence estimates on which risk analysis is based;
3. Integrate consequence results into risk evaluations and prioritization decisions; and
4. Develop, train, and encourage communication and coordination using the necessary crisis management processes.

In summary, the capability would be exercised at the technical level until operationally needed, possibly on short notice.

4
Conclusion

The United States and its allies are facing serious and evolving threats to nuclear security and peace. Examples include new strategic conditions with two or more adversaries with large nuclear arsenals; domestic and foreign terrorist organizations with possible connections between them; and adversaries obtaining other powerful capabilities (i.e., biological, chemical, cyber weapons) and adopting first-use doctrines.

The ability of the United States to maintain deterrence in peace and restore deterrence in war will be strongly influenced by thoughtful and well-done risk analysis that allows the U.S. government decision makers to have access to a wider array of possible outcomes and choices—even those “contingencies,” as stated by Thomas Schelling, that look unfamiliar and strange and, therefore, improbable. The United States as a nation has much it can do to improve that ability.

References

Biden, J.R. 2022. "National Security Strategy." October. https://www.whitehouse.gov/wp-content/uploads/2022/10/Biden-Harris-Administrations-National-Security-Strategy-10.2022.pdf.

Bush, G.W. 2002. "The National Security Strategy of the United States of America." September. Washington, DC. https://history.defense.gov/Portals/70/Documents/nss/nss2002.pdf?ver=oyVN99aEnrAWijAc_O5eiQ%3d%3d.

Clinton, W.J. 1994. "A National Security Strategy of Engagement and Enlargement." Washington, DC. https://history.defense.gov/Portals/70/Documents/nss/nss1994.pdf.

DHS (Department of Homeland Security). 2021. "Unclassified Remarks for Phase 1." (DHS, Phase I, 2021).

DIA (Defense Intelligence Agency). 2009. "A Tradecraft Primer: Structured Analytic Techniques for Improving Intelligence Analysis," 2nd edition. Directorate for Analysis Research. March. https://www.dia.mil/FOIA/FOIA-Electronic-Reading-Room/FileId/161442.

DoD (Department of Defense). 2022. "National Defense Strategy." https://media.defense.gov/2022/Oct/27/2003103845/-1/-1/1/2022-NATIONAL-DEFENSE-STRATEGY-NPR-MDR.PDF.

Grabo, C.M. 2002. *Anticipating Surprise: Analysis for Strategic Warning*. J. Goldman (ed.). Center for Strategic Intelligence Research. Bethesda, MD: Joint Military Intelligence College.

Granholm, J.M. 2023. "Russia's Ongoing Assault on Nuclear Safety and Security Endangers the World." *The Hill*. March 14. https://thehill.com/opinion/congress-blog/3900184-russias-ongoing-assault-on-nuclear-safety-and-security-endangers-the-world.

IAEA (International Atomic Energy Agency). 2022. "Verification and Monitoring in the Islamic Republic of Iran in Light of United Nations Security Council Resolution 2231 (2015)." September 7. GOV/2022/39. gov2022-39.pdf (iaea.org).

IOM (Institute of Medicine). 2013. *Environmental Decisions in the Face of Uncertainty*. Washington, DC: The National Academies Press. https://doi.org/10.17226/12568.

IPCC (International Panel on Climate Change). 2022. "Summary for Policymakers." H.-O. Pörtner, D.C. Roberts, E.S. Poloczanska, K. Mintenbeck, M. Tignor, A. Alegría, M. Craig, S. Langsdorf, S. Löschke, V. Möller, A. Okem (eds.). In *Climate Change 2022: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge, UK: Cambridge University Press. https://doi.org/10.1017/9781009325844.001.

NASEM (National Academies of Sciences, Engineering, and Medicine). 2023. *Risk Analysis Methods for Nuclear War and Nuclear Terrorism*. Washington, DC: The National Academies Press. https://doi.org/10.17226/26609. (Phase I report).

NDSC (National Defense Strategy Commission). 2018. *Providing for the Common Defense: The Assessment and Recommendations of the National Defense Strategy Commission*. United Institute of Peace. Washington, DC. https://www.usip.org/sites/default/files/2018-11/providing-for-the-common-defense.pdf.

Roberts, B. 2020. *On Theories of Victory, Red and Blue*, Livermore Papers on Global Security No. 7. Lawrence Livermore National Laboratory. Center for Global Security Research.

Roberts, B. 2022. Briefing by Brad Roberts, director, Center for Global Security Research, Lawrence Livermore National Laboratory. Meeting 3, November.

Roberts, P. 2017. "Designing Conceptual Failure in Warfare." *RUSI Journal* 162(1):14–23.

USSTRATCOM (U.S. Strategic Command). 2021. Nuclear Planning Guidance. Presentation slides at the May 27, 2021, committee meeting.

White House. 2022. "Joint Statement of the Leaders of the Five Nuclear-Weapon States on Preventing Nuclear War and Avoiding Arms Races." January 3. https://www.whitehouse.gov/briefing-room/statements-releases/2022/01/03/p5-statement-on-preventing-nuclear-war-and-avoiding-arms-races.

Wohlstetter, R. 1962. *Pearl Harbor: Warning and Decision*. Stanford, CA: Stanford University Press.

Appendixes

A
Biographies of Committee Members, Consultants, and Staff

WILLIAM C. OSTENDORFF (U.S. Navy, Retired), *Co-Chair*, is a nuclear expert and a nuclear industry consultant and serves on several corporate boards. He joined the Naval Academy's Political Science Department as the Class of 1960 distinguished visiting professor in national security in August 2016. He served as the U.S. Naval Academy Distinguished visiting professor of national security from 2016 to 2017. Captain Ostendorff served as the principal deputy administrator at the National Nuclear Security Administration (NNSA) in the Bush administration (2007–2009) and as a commissioner at the U.S. Nuclear Regulatory Commission (NRC, 2010–2016) in the Obama administration prior to joining the Naval Academy faculty. From 2003 to 2007, he was a member of the staff of the House Armed Services Committee. Captain Ostendorff was an officer in the U.S. Navy from 1976 until he retired in 2002. Entering the Rickover Nuclear Navy, he served on six submarines. During his naval career, he commanded a nuclear attack submarine and a nuclear attack submarine squadron and served as the director of the Division of Mathematics and Science at the Naval Academy. His military decorations include four awards of the Legion of Merit and numerous unit and campaign awards. In 2023, the American Nuclear Society awarded him the Dwight D. Eisenhower medal. Captain Ostendorff earned a bachelor's degree in systems engineering from the Naval Academy, a law degree from the University of Texas, and a master's degree in international and comparative law from Georgetown University.

M. ÉLISABETH PATÉ-CORNELL, *Co-Chair*, is the Burt and Deedee McMurtry professor and founding chair of the Department of Management Science and Engineering at Stanford University. Her specialty is engineering risk analysis and risk analysis with applications to complex systems such as space, medical, and intelligence. Her research has focused on explicit consideration of human and organizational factors in the analysis of failure risks and on the use of game theory in risk analysis. Applications in recent years have included counter-terrorism, nuclear counter-proliferation problems, and cyber risk analysis. She was a member of several boards, including Aerospace, Draper, and In-Q-Tel and monitor of the Society for Risk Analysis (1995). She was a member of the President's Foreign Intelligence Advisory Board until December 2008. She is currently a member of the NASA Advisory Council. She was awarded the 2021 IEEE Ramo medal in systems engineering and systems science. She received a PhD in engineering economic systems from Stanford University. Dr. Paté-Cornell was elected to the National Academy of Engineering in 1995.

VICKI M. BIER recently retired from a joint appointment as a professor in the Department of Industrial and Systems Engineering and the Department of Engineering Physics at the University of Wisconsin–Madison, where she directed the Center for Human Performance and Risk Analysis (formerly the Center for Human Performance in Complex Systems) from 1995 to 2021. She was recently appointed to the Advisory Committee on Reactor Safeguard at NRC. She has more than 40 years of experience in risk analysis for the nuclear power, chemical, petrochemical, and aerospace industries, as well as homeland security and critical-infrastructure protection. Dr. Bier's recent research has focused on applications of risk analysis and related methods to problems of security, critical infrastructure protection, and emergency management. Dr. Bier received the Women's Achievement Award from the American Nuclear Society in 1993 and was elected a fellow of the Society for Risk Analysis in 1996, from which she received the Distinguished Achievement Award in 2007. She is also a past president of the Decision Analysis Society and editor-in-chief of the society's flagship journal *Decision Analysis*. She has participated in panels, committees, and subcommittees of the National Academies of Sciences, Engineering, and Medicine dealing with radioactive waste management and a committee to review the Department of Homeland Security's approach to risk analysis and served on the Board on Mathematical Sciences and Analytics from 2014 to 2016. She received a PhD in operations research from the Massachusetts Institute of Technology in 1983 and a BS in mathematical sciences from Stanford University in 1976.

M. ELAINE BUNN is a consultant on strategic issues, with 40 years of experience in the U.S. government working on defense policy. She is based in Washington, DC. She addresses international audiences on nuclear policy, extended deterrence, and missile defense. Her writings include articles and book chapters on deterrence, assurance of allies, strategic planning, nuclear policy, missile defense, arms control, and preemption. She serves as a mentor for university students to mid-career professionals, including through the Project for Emerging Leaders at the Center for the Study of Weapons of Mass Destruction, National Defense University, and the Project on Nuclear Issues at the Center for Strategic and International Studies. She is a non-resident senior associate fellow at the Royal United Services Institute in London and chair of the Nuclear Deterrence External Advisory Board at Sandia National Laboratories. Ms. Bunn served as the Deputy Assistant Secretary of Defense for Nuclear and Missile Defense Policy (DASD/NMD) from 2013 to early 2017. Responsibilities included defining requirements for future capabilities, reviewing and adjusting operational planning, and leading extended deterrence discussions with allies. Prior to being appointed DASD/NMD, Ms. Bunn was a Distinguished Research Fellow in the Center for Strategic Research at the National Defense University's Institute for National Strategic Studies, where she headed a project on future strategic concepts. Ms. Bunn, a 1988 graduate of the National War College, received an MA from the Johns Hopkins University School of Advanced International Studies in 1980. She was a Fulbright Scholar at the Université de Neuchâtel, Switzerland, in 1974–1975, after graduating from the University of Georgia with a BA in international political communications.

NANCY J. COOKE is a professor of human systems engineering and the director of the Center for Human and Artificial Intelligence and Robot Teaming at Arizona State University. She is trained as a cognitive psychologist and has been doing research on assessing teamwork for nearly 25 years. Dr. Cooke received her BA in psychology from George Mason University in 1981 and her MA and PhD in cognitive psychology from New Mexico State University in 1983 and 1987, respectively. Dr. Cooke chaired the National Academies' Board on Human-Systems Integration from 2012 to 2016 and was a member of the consensus study report *Safety and Security of Commercial Spent Nuclear Fuel Storage* published in 2006.

RAYMOND JEANLOZ is a professor of Earth and planetary science and astronomy at the University of California, Berkeley, and the Annenberg Distinguished Visiting Fellow at the Hoover Institution, Stanford University. In addition to his scientific research on the evolution of planetary interiors and properties of materials at high pressures, he works at the interface between science and policy in areas related to national and international security, resources and the environment, and education. Dr. Jeanloz is a member of the JASON group that provides technical advice to the U.S. government and chairs the National Academies' Committee on International Security and Arms Control. He has served on the Secretary of State's International Security Advisory Board and is past chair of the National Academies' Board on Earth Sciences and Resources. He is an elected fellow of the American Academy of Arts and Sciences, the American Association for the Advancement of Science (AAAS), the American Geophysical Union, the American Physical Society, and the Mineralogical Society of America. Dr. Jeanloz holds a PhD from the California Institute of Technology.

RICHARD W. MIES is the chief executive officer of The Mies Group, Ltd., a consulting corporation that provides strategic planning and risk assessment advice on international security, energy, and defense issues. He completed a distinguished 35-year career as a nuclear submariner in the U.S. Navy and commanded U.S. Strategic Command for 4 years prior to retirement in 2002. He served as a senior vice president of the Science Applications International Corporation from 2002 to 2007. He also served as the chair of the Department of Defense Threat Reduction Advisory Committee from 2004 to 2010 and as vice chair of the Secretary of Energy Advisory Board. He presently serves as the chair of the Strategic Advisory Group of the U.S. Strategic Command and is a member of the board of governors of Lawrence Livermore National Laboratory and a member of the National Academies' Committee on International Security and Arms Control. He completed post-graduate education at Oxford University, the Fletcher School of Law and Diplomacy, and Harvard University.

GREGORY S. PARNELL is a professor of practice in industrial engineering in the Department of Industrial Engineering and the director of the Master of Science in Operations Management (the university's largest graduate program) and Master of Science in Engineering Management programs at the University of Arkansas. His research focuses on decision analysis, risk analysis, systems engineering, and resource allocation for defense; intelligence; homeland security; and environmental management. He is a professor emeritus at the U.S. Military Academy at West Point. Previously, he served as a professor of systems engineering at West Point, a distinguished visiting professor at the U.S. Air Force Academy, an associate professor at Virginia Commonwealth University, and a department head at the Air Force Institute of Technology. Dr. Parnell is a former president of the Decision Analysis Society of the Institute for Operations Research and Management Science (INFORMS) and of the Military Operations Research Society (MORS). He has also served as the editor of the *Journal of Military Operations Research*. Dr. Parnell has participated in four National Academies' committees. He chaired the Committee on Methodological Improvements to the Department of Homeland Security's Biological Agent Risk Analysis (2008) and the Review of the Inspection Programs for Offshore Oil and Gas Operations (2021). He was a member of the Committee on Improving Metrics for the Department of Defense Cooperative Threat Reduction Program (2011) and the Committee on Evaluating the Effectiveness of the Global Nuclear Detection Architecture (2013). He is a fellow of International Committee for Systems Engineering, INFORMS, MORS, and the Society for Decision Professionals. He received his BS in aerospace engineering from the University of Buffalo, his ME in industrial and systems engineering from the University of Florida, his MS in systems management from the University of Southern California, and his PhD in engineering-economic systems from Stanford University. Dr. Parnell is a retired Air Force Colonel and a graduate of the Industrial College of the Armed Forces.

SCOTT D. SAGAN is the Caroline S.G. Munro Professor of Political Science, the Bass University Fellow in Undergraduate Education, co-director of the Center for International Security and Cooperation, and senior fellow at the Freeman Spogli Institute, all at Stanford University. He also serves as chair of the American Academy of Arts and Sciences' Committee on International Security Studies. Before joining the Stanford faculty, Dr. Sagan was a lecturer in the Department of Government at Harvard University and served as special assistant to the director of the Organization of the Joint Chiefs of Staff. He is a scholar of nuclear issues and is the author, among other works, of *Moving Targets: Nuclear Strategy and National Security* (1989); *The Limits of Safety: Organizations, Accidents, and Nuclear Weapons* (1993); and, with co-author Kenneth N. Waltz, *The Spread of Nuclear Weapons: An Enduring Debate* (2012). Published articles include "Just and Unjust Nuclear Deterrence," *Ethics and International Affairs* (2023); "Kettles of Hawks: Public Opinion on the Nuclear Taboo and Noncombatant Immunity in the United States, United Kingdom, France and Israel," with Janina Dill and Benjamin A. Valentino, *in Security Studies* (2022) ;and, with Allen Weiner, "The Rule of Law and the Role of Strategy in U.S. Nuclear Doctrine," in *International Security* (2021). In 2017, Dr. Sagan received the International Studies Association's Susan Strange Award, which recognizes the scholar whose "singular intellect, assertiveness, and insight most challenge conventional wisdom and intellectual and organizational complacency" in the international studies community. He was the recipient of the National Academy of Sciences' William and Katherine Estes Award in 2015 for his work addressing the risks of nuclear weapons use and the causes of nuclear proliferation.

HENRY H. WILLIS is a senior policy researcher at the RAND Corporation and a professor of policy analysis at the Pardee RAND Graduate School. Dr. Willis's recent work analyzes terrorism warning indicators; border security efforts; critical infrastructure resilience; and national preparedness to chemical, biological, nuclear, and radiological attacks. He is an active contributor to policy research and is a member of the Council on Foreign Relations and the Risk Sciences Committee of the Society for Risk Analysis. Through his work he testified before Congress; served on several committees of the National Academies; advised government agencies across the United States, Europe, Australia, and the United Arab Emirates; and published dozens of journal articles, reports, and op-eds on applying risk analysis to homeland and national security policy. His work in homeland security policy evolved from his work on program evaluation at the White House Office of Management and Budget and infrastructure design as a water and wastewater engineer. He earned his PhD in engineering and public policy at Carnegie Mellon University.

ALYSON G. WILSON is the associate vice chancellor for National Security and Special Research Initiatives at North Carolina State University (NC State). She is also a professor in the Department of Statistics and the principal investigator for the Laboratory for Analytic Sciences. She is a fellow of the American Statistical Association and AAAS. Her research interests include statistical reliability, Bayesian methods, and the application of statistics to problems in defense and national security. Prior to joining NC State, Dr. Wilson was a research staff member at the Institute for Defense Analyses' Science and Technology Policy Institute in Washington, DC (2011–2013); an associate professor in the Department of Statistics at Iowa State University (2008–2011); a technical staff member in the Statistical Sciences Group at Los Alamos National Laboratory (LANL), where she continues as a guest scientist; and a senior statistician and operations research analyst with Cowboy Programming Resources (1995–1999). Dr. Wilson is the winner of the American Statistical Association Section on Statistics in Defense and National Security Distinguished Achievement Award (2018), NC State Alumni Association Outstanding Research Award (2017), and the Army Wilks Memorial Award (2015). In addition to numerous publications, Dr. Wilson has co-authored a book, *Bayesian Reliability*, and has co-edited two other books, *Statistical Methods in Counterterrorism: Game Theory, Modeling, Syndromic Surveillance and Biometric Authentication* and *Modern Statistical and Mathematical Methods in Reliability*. She has participated in several previous National Academies' studies, including the Committee on Methodological Improvements to the Department of Homeland Security's Biological Agent Risk Analysis. Dr. Wilson received her PhD in statistics from Duke University.

PHILIP D. ZELIKOW is a senior fellow at Stanford University's Hoover Institution and the White Burkett Miller Professor of History at the University of Virginia. His scholarship focuses on critical episodes in American and world history. An attorney and former career diplomat who has served at all levels of U.S. government, his federal service includes work in the five administrations from Reagan through Obama. He has also led bipartisan commissions, serving as the executive director of the 9/11 Commission and, before that, as the executive director of the Carter-Ford National Commission on Federal Election Reform, and most recently, director of the Covid Crisis Group, which produced *Lessons from the Covid War: An Investigative Report*.

CONSULTANTS

DAVID L. BANKS is a professor of the practice of statistics at Duke University. Prior to this, he worked for the National Institute of Standards and Technology, served as the chief statistician of the Department of Transportation, and worked for the U.S. Food and Drug Administration. Dr. Banks was the coordinating editor of the *Journal of the American Statistical Association* and co-founded the journal *Statistics and Public Policy*; he also co-founded the American Statistical Association's Section on National Defense and Homeland Security. He served as the president of the Classification Society and has twice served on the board of directors of the American Statistical Association. He is currently the president of the International Society for Business and Industrial Statistics and a fellow of the American Statistical Association and the Institute of Mathematical Statistics. Dr. Banks recently won the American Statistical Association's Founders Award. His research areas include models for dynamic networks, dynamic text networks, adversarial risk analysis (i.e., Bayesian behavioral game theory), human rights statistics, agent-based models, forensics, and certain topics in high-dimensional data analysis. Dr. Banks holds a BA in anthropology from the University of Virginia (UVA) and master's degrees in mathematics and statistics and a PhD in statistics from the Virginia Polytechnic Institute and State University.

MADHAV V. MARATHE is a distinguished professor in biocomplexity, the division director of the Networks, Simulation Science and Advanced Computing Division at the Biocomplexity Institute and Initiative, and a professor in the Department of Computer Science at UVA. His research interests are in network science, computational epidemiology, artificial intelligence, foundations of computing, socially coupled system science, and high-performance computing. Over the past 25 years, he and his colleagues have developed scalable computational methods to study the social, economic, and health impacts of large-scale natural and human-initiated disasters. Those tools and methods have been used in more than 50 case studies to inform and assess various policy questions pertaining to planning and response in the event of such disasters. Before joining UVA, Dr. Marathe held positions at the Virginia Polytechnic Institute and State University and LANL and was the inaugural George Michael fellow at the Lawrence Livermore National Laboratory. He is a fellow of AAAS, the Society for Industrial and Applied Mathematics, the Association for Computing Machinery, and the Institute of Electrical and Electronics Engineers. He holds a PhD in computer science from the State University of New York at Albany.

PAUL SLOVIC is the president of the research institute Decision Research, which he co-founded with Sarah Lichtenstein and Baruch Fischhoff in 1976. He has been a professor of psychology at the University of Oregon since 1986. Dr. Slovic and his colleagues worldwide have developed methods to describe risk perceptions and measure their impacts on individuals, industry, and society. His recent research examines "psychic numbing" and the failure to respond to global threats from genocide and nuclear war. Dr. Slovic is a past president of the Society for Risk Analysis, from which he received a Distinguished Contribution Award in 1991. In 1993, he received the Distinguished Scientific Contribution Award from the American Psychological Association, and in 1995, he received the Outstanding Contribution to Science Award from the Oregon Academy of Science. Dr. Slovic has received honorary doctorates from the Stockholm School of Economics (1996) and the University of East Anglia (2005). He was elected to the American Academy of Arts and Sciences in 2015 and the National Academy of Sciences in 2016. He received the 2022 Bower Award and Prize, given by The Franklin Institute for foundational and theoretical contributions to the study of decision making. Dr. Slovic has served on numerous committees of the National Academies, including those that produced the reports *Risk Assessment in the Federal Government* (1983) and *Understanding Risk: Informing Decisions in a Democratic Society* (1996). He received his BA from Stanford University and his MA and PhD in psychology from the University of Michigan.

STAFF

JENNIFER (JENNY) HEIMBERG has been a senior program officer at the National Academies since 2011. She is currently the director for the Strategic Council for Research Excellence, Integrity, and Trust. In addition, she has directed studies related to nuclear security, non-proliferation, and nuclear environmental cleanup. Other topics include reproducibility and replicability in science (*Reproducibility and Replicability in Science*, 2019) and estimating the costs of climate damages (*Valuing Climate Damages: Updating the Estimation of the Social Cost of Carbon Dioxide*, 2017). Prior to coming to the National Academies, she was a principal professor staff scientist and worked as a program manager at the Johns Hopkins University Applied Physics Laboratory. She received a BS cum laude in physics from Georgetown University, a BSEE from Catholic University of America, and a PhD in physics from Northwestern University.

MICHAEL JANICKE is a senior program officer on the Nuclear and Radiation Studies Board at the National Academies. Dr. Janicke graduated from Rice University with a BS in chemical engineering and continued his education at the University of California, Santa Barbara, where he earned his PhD in chemical engineering. Following his studies, Dr. Janicke was an Alexander von Humboldt Fellow at the Max Planck Institute for Carbon Research in Mülheim an der Ruhr. While in Germany, he worked with Professor Ferdi Schüth, former vice president of the German National Science Foundation. In 2000, Dr. Janicke returned to New Mexico as a postdoctoral fellow at LANL and became a staff member in 2002. Most recently he was the center director for REFOCUS, the Resonance Center for Chemical Signatures, and spearheaded efforts in developing new methods to detect chemical threat agents and synthetic opioids at border and airport checkpoints using magnetic resonance techniques. At LANL, he was also involved in several programmatic studies for Enhanced Surveillance Campaigns and Lifetime Extension Programs for the weapons community, participated in NA-22 projects analyzing funded research programs across the Department of Energy complex, and assisted in addressing chemical questions associated with the Medical Isotope and Basic Energy Sciences Heavy Element programs.

BLAKE REICHMUTH is an associate program officer currently with the Board on Mathematical Sciences and Analytics at the National Academies. Mr. Reichmuth began his career at the National Academies in 2018 with the Board on Health Care Services in the Health and Medicine Division. He received his MS in mathematical sciences and his BA in mathematics from George Mason University. While working on his MS he also contributed to research at George Mason University's Biomedical Research Laboratory and assisted with the 2020 report *Differences in Transcriptional Dynamics Between T-cells and Macrophages as Determined by a Three-State Mathematical Model*.

MICHELLE K. SCHWALBE is the director of the Board on Mathematical Sciences and Analytics and the National Materials and Manufacturing Board at the National Academies. She first joined the National Academies in 2010 as a Christine Mirzayan Science & Technology Policy Fellow. She previously held positions at Oak Ridge National Laboratory and Lawrence Livermore National Laboratory working on computing and mathematics research topics. Dr. Schwalbe has a PhD in mechanical engineering from Northwestern University, where she researched Bayesian uncertainty quantification for biomedical materials models and received an MS in engineering science and applied mathematics and a BS in applied mathematics specializing in computing from the University of California, Los Angeles.

B
Request for Information

During its data collection for Phase II, the committee developed a set of questions pertaining to nuclear war risks and a different set pertaining to nuclear terrorism risks.

DATA, INFORMATION, BRIEFING REQUESTS—PHASE II

The committee's focus is on meeting all of the elements of its tasking (statement of task). At a high level, the committee requests information relevant to addressing the tasks below. During Phase I of the study, the committee focused on addressing Tasks 1–3, using unclassified, publicly available information. For Phase II, the committee will revisit Tasks 1–3, with access to relevant classified information and will focus on Tasks 4 and 5, which explore the interface between risk assessment and strategy development by U.S. policy makers.

Information includes reports, policy statements, briefings, site visits, and potential observation of exercises.

Specific questions currently of interest to the committee related to assessing risks related to nuclear war:

The committee will explore the intersection between those conducting risk assessments and decision makers (consumers of risk assessments) examining assumptions that are made by risk analysts and how are they communicated to the decision makers; and assumptions that are made by the decision makers when incorporating risk assessments into strategy and decisions.

Specific questions below:

- Are there any written materials on relevant U.S. government (USG) risk analyses and national nuclear strategies that the committee should review in advance of your presentation?
- Role in USG strategies: What role does your organization play in USG development of (a) risk assessment of nuclear war; and (b) nuclear or national security strategies?
  - What assumptions are made in your role?
  - How does your work contribute to nuclear or national strategy documents? Identify the documents or statements.
- Current risk methods: What methods and approaches for assessing risk related to nuclear war are used in your roll/organization?
  - Include both quantitative and qualitative methods
  - How are scenarios identified for exercises/war games and what assumptions are made in planning and conducting those events? What recent relevant exercises or war games have taken place that the committee can be briefed on?
- To USG leadership briefing the committee (i.e., STRATCOM, Joint Chiefs, NSC, and others):
  - What does your organization believe to be the best value added by this committee?

  - Describe your process for internally vetting/challenging assumptions and risk estimates. How does that process interact with the NSC staff (this goes to decision making)?
  - Describe how your organization uses red teaming in order to better assess risk estimates and their underlying methodology.
- Recent and past events and risk assessment: In the questions below, the committee requests information on the methods, assumptions, and changes made to risk assessment approaches in response to real-world events of relevance to the risk of nuclear war.
  - For risk analyses related to the war in Ukraine, provide details on how methods were used and updated as the situation evolved.
  - What risk analyses were used to guide the decision in March 2022 to delay ICBM tests, if any?
  - What risk methods were used to assess risks of Russian invasion and were they successful in predicting/preparing the U.S. for actions to take to reduce risk of nuclear war? What, if any, changes were made to the assumptions used by those methods after the invasion?
  - Have risk methods been used to assess the impact of sanctions on Russia? If so, what assumptions were made?
  - How were risk analysis outputs used in responding to Russian invasion? And China's response?
  - Was Putin's underestimate of the Ukrainian response/resistance predicted? Where in risk methods/models would this have been captured?
  - What actions have been taken in response to past "near misses" and how have those actions been assessed to reduce risk of nuclear war? What has changed to increase the risk? Selected incidents include: Cuban Missile Crisis, 1983 Able Archer Exercise, and 1991 George H.W. Bush de-alerting U.S. strategic nuclear forces. Other examples are welcomed.
  - How does the missile defense system's capability enter into risk assessments, if at all?
- Feedback on our study:
  - From your perspective, what topics should the committee be sure to address in this study?
  - What types of recommendations would be most useful to you?
  - What question(s) haven't we asked, but should have?

Specific questions currently of interest to the committee related to assessing risks related to nuclear terrorism:

High-level questions:

1. Describe your role in the coordination in the inter-agency (NNSA, DOE, State, NSC, IC, etc.) in taking a whole of USG approach for addressing the risks of nuclear terrorism. Who performs or is responsible for formulating an overall USG risk estimate of nuclear terrorism? If there is not a single entity, should there be? What methods are used to estimate the risk?
2. In your opinion, what think tanks/NGOs/national labs/academics are doing "state of the art" work in employing risk analysis methods in looking at nuclear terrorism.
3. Given what you know about this Committee's Statement of Task, where and how do you think this Committee can add value in the use of risk analysis methods to address nuclear terrorism?

Specific examples of risk assessments to guide decisions/strategy:

1. Explain how risk estimates are used to arrive at non-proliferation program budget decisions. What methods are used in developing these risk estimates?

2. Does your organization compare the risk of the detonation of an improvised nuclear device to the deployment of a radiological dirty device or other radiological devices? If so, explain how risk estimates are used in this comparison?
3. Explain how your organization uses risk estimates to assess the physical security of nuclear materials overseas that are covered by USG non-proliferation funding. Explain the specific methods uses in this process.
4. How do cybersecurity vulnerabilities factor into your organization's risk estimates for prioritizing securing nuclear materials domestically and overseas?
5. Describe your organization's risk informed process to determine what nuclear materials (other than HEU and weapons grade plutonium) your program should fund/support.

Specific examples of risk assessments:

1. Update the committee on the Department of Energy's graded approach for nuclear material characterization. Is this approach accepted across the USG?
2. Recently, Russia has made allegations that Ukraine planned to deploy a radiological dirty bomb. Explain your organization's role in the inter-agency process in assessing the validity of this threat as well as in preparing possible response options for the USG.
3. In the context of the Russian invasion of Ukraine, specifically the Russian attacks against and in the vicinity of the Zaporizhzhia Nuclear Power Plant, has there been a uniform USG approach to addressing the risks of nuclear fuel meltdown or spent fuel pool damage?

C
List of Phase II Briefers

MEETING 1: AUGUST 24 AND 25, 2022 (PENTAGON AND KECK, WASHINGTON, DC)

National Academies of Sciences, Engineering, and Medicine, Committee on International Security and Arms Control (CISAC)
Micah Lowenthal, Senior Director of CISAC

Department of Defense, Office of the Secretary of Defense (OSD/OUSD)
Michael Hodgkin (OSD)
Matt Kurtz (OUSD Policy)

Joint Staff, Strategic Stability (J5)
Dr. Austin G. Long, Acting Director, J5 and Strategic Stability

Joint Staff Nuclear Terrorism Assessments (J3 and J5)
COL Jeremiah Aeschleman, Ms. Heather Burgess, Ms. Sarah Pisarcik, Mr. Scott Dunn

U.S. Special Operations Command (SOCOM)
Ricky Boyer, Joint Special Operations University and J10

National Security Council
Pranay Vaddi, Senior Director, and others

Missile Defense Agency
Mr. Dennis Mays, MDA Director for Engineering

Defense Threat Reduction Agency (DTRA), Strategic Integration
Mr. Donald Wenzlick, Chief, Strategic Trends Division

Greg Weaver, Strategy to Plans, LLC

MEETING 2: OCTOBER 24 AND 25, 2022 (VISIT TO U.S. STRATEGIC COMMAND [USSTRATCOM], OMAHA, NEBRASKA)

USSTRATCOM
BG John Weidner, J5P (host to the committee)

Session 1: Escalation Dynamics/Decision Calculus
Mr. Rich McManus, J5STO
Ms. Jennifer Bradley, J57

Session 2: USSTRATCOM Risk Assessment Methodologies
Mr. Pete Huggins, J5P

Session 3: Uses of and Alternative Approaches to Strategic Risk Assessment
Roundtable: Facilitator BG Weidner

Session 4: Panel Discussion on Risk Methods and Uses
BG John Weidner, J5P
Maj Gen John Nichols, J3
Mr. Bob Taylor, J8
Brig Gen Ricky Mills, J2
Mr. Chad Stevenson, NEC
Mr. JB Miller, J7

Session 5: USSTRATCOM War Gaming Design, Execution, and Assessment
Dr. Terry Buckman, J712
Mr. Joe Williams, J571

Session 6: Discussion on Potential Solutions to Address Strategic Deterrence Gaps
Mr. Steve Pettit, DJ5
Mr. Pat McKenna, J5/STA
Mr. Bob Taylor, J8
Mr. Chad Stevenson, NEC

MEETING 3: NOVEMBER 7, 2022 (UNCLASSIFIED VIA ZOOM)

Brad Roberts, LLNL

MEETING 4: DECEMBER 12 -14, 2022 (FORRESTAL AND KECK, WASHINGTON DC)

Gen (Retired) James Mattis

DOE-IN: Rebecca Lucast, Branch Chief, Security Branch, NMIP; Amanda Weaver, Deputy Director, NMIP; Sarah Bender; Dan Migrone, Branch Chief, Nuclear Terrorism and Security Branch, Foreign Nuclear Programs (FNP) Division; Donald Puglisi, Director, FNP; Drew Nichols, Director, NMIP

NNSA: Jay Tilden, NNSA Associate Administrator and Deputy Under Secretary for Counterterrorism and Counterproliferation (NA-80); Dallas Boyd, executive director and chief of staff for NNSA, NA-80

NIC: NIO for Counterterrorism, John Murphy

Amb. Rose Gottemoeller, Stanford University (previously with NATO and Department of State)

Major General (Retired) Julie Bentz

Department of State: Aaron Miles, Senior Advisor, Office of Strategic Stability and Deterrence Affairs, Arms Control, Verification, and Compliance (AVC); Constantinos (Costa) Nicolaidis, Acting Director, Office of WMD Terrorism, Bureau of International Security and Nonproliferation (ISN); Nicole Rothenberg, Program Advisor, Cooperative Threat Reduction program, ISN

Caryn Leslie, Director of ICSB, National Academies
National Intelligence Council (NIC): James Murphy, National Intelligence Officer for WMD

MEETING 5: JANUARY 26 AND 27, 2023 (KECK, WASHINGTON, DC)

Jennifer Pavlick, Risk Lead, Countering Weapons of Mass Destruction (CWMD) Directorate, DHS

Jeff Cooper, PANTHR Program Manager, Science and Technology Directorate, DHS

Thomas Breske, Senior Advisor, WMD-CT Division, National Counterterrorism Center (NCTC), ODNI

Drew Ryan, Issues Manager, WMD-CT Division, NCTC and National Counter-proliferation and Biosecurity Center (NCBC), ODNI

Mark L. Sward, Chief, Nuclear Effects Division, Nuclear Technologies Department, Research and Development Directorate, DTRA

Caleb Fullerton, Intelligence Analysis, Federal Bureau of Investigation

MEETING 6: MARCH 23 AND 24, 2023 (KECK, WASHINGTON, DC)

Thomas W. Geyer, Director, Strategic Initiatives, White House Military Office, DoD

Richard C. Johnson, Deputy Assistant Secretary of Defense (DASD) for Nuclear and Countering Weapons of Mass Destruction (N-CWMD), Office of the Secretary of Defense, DoD