THE U.S. NUCLEAR WAR PLAN: A TIME FOR CHANGE

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ABOUT NRDC

NRDC is a national nonprofit environmental organization with over 500,000 members and contributors nationwide. Since 1970, NRDC's scientists, lawyers, and staff have been working to protect the world's natural resources and to improve the quality of the human environment. NRDC has offices in New York City, Washington, D.C., San Francisco, and Los Angeles.

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EXECUTIVE SUMMARY

Through the use of personal computers, customized computer software, and unclassified databases, the Natural Resource Defense Council (NRDC) is now able to model nuclear conflict and approximate the effects of the use of nuclear weapons. For the first time, this allows non-governmental organizations and scholars to perform analyses that approximate certain aspects of the U.S. nuclear war plan known as the Single Integrated Operational Plan (SIOP).

Initiated during the Eisenhower administration, the SIOP is the war plan that directs the employment of U.S. nuclear forces in any conflict or scenario, and is the basis for presidential decision-making regarding their use. The plan results from highly classified guidance from the President, the Secretary of Defense, and the Joint Chiefs of Staff. The Joint Chiefs of Staff then set requirements for how much damage our nuclear warheads must achieve. Most of the requirements call on U.S. Strategic Command to target Russia, but China and other nations are also viewed as potential adversaries.

The SIOP's logic and assumptions about nuclear war planning influence U.S. national security policy, arms control strategy, and international politics. Though the Cold War has ended, and the SIOP has been through a number of reforms as forces have been reduced, it continues to dictate all matters concerning the U.S. preparations for nuclear war. It establishes mock nuclear war scenarios and requirements that shape U.S. negotiating positions in the Strategic Arms Reduction Treaty (START) arms control process. The SIOP also determines what number of nuclear warheads must be kept at various alert levels.

As the SIOP is one of the most secret documents in the U.S. government, it is difficult to discover what the specific assumptions are upon which it rests. Congress has been powerless to influence the SIOP, and even presidents have only a superficial understanding of the process of nuclear war planning. The secrecy is ostensibly justified to protect certain characteristics about U.S. nuclear forces and warheads, various nuclear weapons effects information, and the specific targets chosen in Russia. But all of these data are known well enough today to provide a quite sophisticated approximation of the actual SIOP assumptions, and the effects of its various nuclear war scenarios. One of the most significant changes since the end of the Cold War has been the greater openness in Russia whereby a high quality database of nuclear, military, and industrial targets can be created using open sources.

Given the central role of the SIOP in national security, nuclear weapons, and arms control policy, NRDC decided to create a tool that will help the non-governmental community assess nuclear war planning and its impacts. We have compiled our own databases of information on weapons, population, effects, and targets to recreate the most important calculations of nuclear war planning. We integrated an enormous quantity of data from open sources, including commercial data on the Russian infrastructure, official arms control data about the structure of Russian nuclear forces, declassified U.S. documents, census and meteorological data, U.S. and Russian maps and charts, U.S. government and commercial satellite imagery, and U.S. nuclear weapons effects data and software.

Using these resources, we developed a suite of nuclear war analysis models based upon the ESRI ArcView software program. From this model and a database of weapons and targets, we constructed and analyzed in detail two quite different scenarios of a possible nuclear attack on Russia:

- ▶ A major U.S. thermonuclear "counterforce" attack on Russian nuclear forces. For this attack, we employed approximately 1,300 strategic warheads using current U.S. weapons. We calculated the damage to these targets and the resulting civilian deaths and injuries.
- ▶ A U.S. thermonuclear "countervalue" attack on Russian cities. For this attack, we used a "minimum" force (150 silo-based intercontinental ballistic missile warheads or 192 submarine-launched ballistic missile warheads). We assessed the ensuing civilian deaths and injuries.

FIGHTING REAL NUCLEAR WARS: THE RESULTS

We used actual data about U.S. forces and Russian targets to approximate a major counterforce SIOP scenario. Our analysis showed that the United States could achieve high damage levels against Russian nuclear forces with an arsenal of about 1,300 warheads—less than any of the proposals for a START III treaty. According to our findings, such an attack would destroy most of Russia's nuclear capabilities and cause 11 to 17 million civilian casualties, 8 to 12 million of which would be fatalities.

Our analysis concluded that in excess of 50 million casualties could be inflicted upon Russia in a "limited" countervalue attack. That attack used less than three percent of the current U. S. nuclear forces, which includes over 7,000 strategic nuclear warheads.

One of the historic tenets of nuclear orthodoxy—influential in inspiring the original SIOP—was that countervalue attacks against cities and urban areas were "immoral" whereas counterforce attacks against Soviet (and later, Russian) nuclear forces were a better moral choice. The implied assumption and intent was that attacks could be directed against military targets while cities and civilian concentrations were spared. In reality, things are not so simple, nor can there be such pure isolation between civilian and military. Most difficult of all is to find moral benchmarks when it comes to the targeting of nuclear weapons.

Our analysis challenges that basic assumption. Even the most precise counterforce attacks on Russian nuclear forces unavoidably causes widespread civilian deaths due to the fallout generated by numerous ground bursts. While the intention to avoid civilian casualities is important and is probably included in the guidance, nuclear weapons by their nature live up to their billing as "Weapons of Mass Destruction." We saw this clearly in our simulation of a counterforce attack. We found the effects were complex and unpredictable and therefore uncontrollable from a war planner's perspective. These included such variables as the proximity of urban centers to military targets, whether the population was sheltered or not, and the speed and direction of the wind.

The point here is not to argue for attacking Russian cities or for attacking Russian forces as U.S. nuclear policy. But given the vast number of deaths that occur with the use of a few weapons, we have to ask why the U.S. nuclear forces need to be so large? If the United States can destroy Russia's standing forces and cause 11 to 17 million casualties in a counterforce attack, should not that be enough to "deter" any conceivable attack by Russia? To go a step further, if the United States went to a minimum force, it would still be able to cause upwards of 50 million casualties. That fact too should be enough to convince Russia or anyone not to use nuclear weapons against the United States.

In light of the findings from our computer simulation of the two nuclear scenarios, we are more convinced than ever that the basic assumptions about U.S. nuclear deterrence policy, and the possession of huge nuclear arsenals needs to be re-examined. The logic of the nuclear war plan expressed in the current SIOP ignores the grotesque results that would occur if the weapons were used. Those results need to be exposed.

WHAT WE RECOMMEND

1. Unilaterally reduce U.S. nuclear forces and challenge Russia to do the same. The sole rational purpose for possessing nuclear weapons by the United States is to deter the use of nuclear weapons by another country. Recommendations for specialized arsenals to fulfill a variety of illusory roles for nuclear weapons are expressions of irrational exuberance. At this stage in the disarmament process, a U.S. stockpile numbering in the hundreds is more than adequate to achieve the single purpose of deterrence. Even that number, as we have seen, is capable of killing or injuring more than a third of the entire Russian population, and destroying most major urban centers.

The current SIOP is an artifact of the Cold War that has held arms reduction efforts hostage. It is time to replace it with something else.

2. Clarify the U.S. relationship with Russia and reconcile declaratory and employment policy. In his May speech at the National Defense University, President Bush said, "Today's Russia is not our enemy." That said, the United States has not yet decided whether Russia is our enemy or our friend, or something in between. The act of targeting defines an individual, a group, or a nation as an enemy. We continue to target Russia with nuclear weapons and devise options and plans for their use. The process itself reduces Russia from flesh and blood to models and scenarios, allowing the contradictory stance to continue. If our words and our actions are to correspond, it is obvious that major changes must take place in the way the United States postures its nuclear forces and plans for their use.

3. Abandon much of the secrecy that surrounds the SIOP and reform the process. Any discussion of U.S. nuclear policy and strategy is undermined by the fact that most of the details surrounding the SIOP are highly guarded secrets. Because of compartmentalization, only a very few have an understanding of the SIOP. The presidential and Pentagon guidance too is so closely held, that no one can question the assumptions or the logic. The nuclear war planning function now resident within U.S. Strategic Command has become a self-perpetuating constituency that needs fundamental reform. Much of the secrecy that surrounds the SIOP can be abandoned without any loss to national security. Therefore, a joint civilian-military staff, with Congressional involvement and oversight, should plan the use of nuclear weapons.

4. Abolish the SIOP as it is currently understood and implemented. Having a permanent war plan in place that demands widespread target coverage with thousands of weapons on high alert is a recipe for unceasing arms requirements by the Pentagon and a continuing competition with Russia and others. It is for this reason that we conclude that the over-ambitious war plan is a key obstacle to further deep arms reductions. The current SIOP is an artifact of the Cold War that has held arms reduction efforts hostage. It is time to replace it with something else.

5. Create a contingency war planning capability. Under new presidential guidance, the United States should not target any country specifically but create a contingency war planning capability to assemble attack plans in the event of hostilities with another nuclear state. This new paradigm would alleviate the requirement for possessing large numbers of weapons and eliminate the need for keeping those that remain on high levels of alert. This shift would also help break the mind-set of the Cold War. We are in agreement with President Bush when he says that we must get beyond the Cold War. We believe, however, that his approach is not the "clear and clean break with the past" that he says he wants. Instead, by assuming a wider range of uses for nuclear weapons, by making space a theater for military operations, and by considering new or improved nuclear warheads for a future arsenal, President Bush is offering more of the same.

6. Reject the integration of national missile defense with offensive nuclear deterrent forces. Current, worst-case SIOP planning demands that both the United States and Russia prepare for the contingency of striking the other first, though it is not stated U.S. or Russian declaratory policy. Introducing national missile defense, which invariably complements offensive forces, will exacerbate the problem. The technological challenges of national missile defense are formidable, the price tag enormous, and if deployed, will provoke a variety of military responses and countermeasures, leaving the U.S. less secure rather than more secure. China, for instance, has long had the ability to deploy multiple warheads on its ballistic missiles and has chosen not to do so. Currently only a small number, less than two-dozen Chinese single-warhead missiles, can reach the United States. A guaranteed way to increase that number would be for the United States to abrogate the Anti-Ballistic Missile Treaty and to deploy a national missile defense system. Furthermore, national missile defenses would likely undermine opportunities for deeper reductions.

CHAPTER ONE

PURPOSE AND GOALS

Today's Russia is not our enemy.

President George W. Bush, May 1, 2001

In 1999, the Natural Resources Defense Council's (NRDC) Nuclear Program initiated a Nuclear War Plans Project to spur new thinking about nuclear arms reductions and the risks and consequences of nuclear conflict. What we faced then—and what we face now—was an arms reduction process at a standstill. On the surface, the standstill was caused by the failure to ratify the START II Treaty. It was further exacerbated by disagreements over the details of START III reductions and the impact of a U.S. missile defense program. But the real stumbling block was a "veto" exerted by the United States' central nuclear war plan—the Single Integrated Operational Plan (SIOP). Initiated in the Cold War, the SIOP continues to dictate U.S. nuclear war matters and hold all reduction options hostage.

No one doubts that the SIOP's logic and assumptions about nuclear war planning influence U.S. national security policy, arms control strategy, and international politics. What is less clear is what those specific assumptions are, and whether the nuclear war planning process is rational, or is actually a hall of mirrors, creating extravagant requirements, yet blind to what would happen if they were used. Most of the assumptions about planning for nuclear war are put beyond debate because of excessive government secrecy. The public and the experts are also at a disadvantage by lacking tools to perform independent assessments of the fundamental premises of nuclear deterrence. NRDC set out to change that.

Given the central role that the SIOP plays in armament issues and national security policy, NRDC decided to create a tool that would help us understand this largely secret process.

Given the central role that the SIOP plays in armament issues and national security policy, NRDC decided to create a tool that would help us understand this largely secret process. We began our project when, for the first time, information and computer power could allow a non-governmental organization to recreate many of the calculations of nuclear war planning, thereby allowing a credible approximation of the U.S. SIOP. Changes in Russia have resulted in the increasing availability of detailed information about its nuclear and military forces, as well as the supporting civil, military, and industrial infrastructures. High-quality maps, satellite photography, population distribution data, and meteorological data are now available electronically. We also have a basic understanding of the SIOP itself, its structure, and many of the assumptions that go into it. State-of-the-art weapons-effects models are also available and can be run on personal computers. All of these new resources can be combined in sophisticated geographic information systems (GIS) with customized visualization software. The result is a high quality, real-world target database that simulates nuclear war scenarios using the actual data about forces, weapons, populations, and targets. For the first time, we can now model in an unclassified way the nuclear weapons effects on individual targets and on the Russian civilian population from single, combined, and large-scale attacks.

This report is the first product to utilize the databases and the GIS systems we have developed to simulate nuclear war conflicts. Our goal has been to build a target database using a variety of unclassified data. We have developed a database for Russia that contains almost 7,000 records for prospective nuclear targets extending to over 90 fields of data. We have integrated population data with the target database. The target and population databases are the underpinnings of an analytical tool that we have designed to enable us to evaluate different scenarios at current force levels or for smaller proposed levels in the future. This model allows us to evaluate a variety of nuclear strategies and targeting concepts.

Our databases and tools have provided us with a greater appreciation of the complexity of the SIOP process, a process that transforms potential adversaries from flesh and blood into targets and outputs. The scenarios we present in our report have been arrived at through thousands of time-consuming calculations. They determine the levels of damage to targets and the statistical probabilities of civilian casualties depending upon monthly variation in wind patterns, and whether the civilian population is sheltered or in the open.

The major objectives of this initial application of our simulation tool are:

- To provide an independent, open assessment of the fundamental premises of the current U.S. nuclear war plan, known as the Single Integrated Operational Plan
- To analyze the levels of damage inflicted by striking nuclear weapons targets with greatly reduced forces
- To heighten public and policymaker awareness of the present-day consequences of the use of nuclear weapons, including the risks to specific targets in Russia
- To encourage the adoption of new Presidential guidance that directs the elimination of the SIOP as it is currently defined and practiced, and the deployment of remaining forces at considerably lower alert levels—both essential steps toward deeper reductions in nuclear force levels

Two related objectives should be emphasized as well:

- To introduce a human context into the debate about nuclear strategies and alternative nuclear force structures
- To inject some basic honesty into the nuclear debate by providing data that reveals how a counterforce attack could kill almost as many millions of people as a countervalue attack

As the number of strategic nuclear weapons grew during the Cold War, war planners and insiders tended to theorize about what levels of damage and death a potential adversary (e.g., Soviet Union/Russia) must sustain to be deterred. The measure of sufficiency centered on calculations about how many U.S. weapons would survive after a Soviet/Russian first strike, and the probabilities of achieving high levels of physical destruction against large numbers of dispersed and hardened targets. Absent in this process was any real knowledge about whether the level of damage was perceived by the other side as enough to deter the use of nuclear weapons. All of this theorizing was done in the greatest secrecy, where the characteristics of weapons, the targets, and the content of the nuclear war plan was one of the government's biggest secrets. Even last year during Senate hearings, senior military and civilian leaders in charge of the SIOP refused to answer questions in open or closed testimony regarding how many civilians would be killed in a U.S. nuclear attack against Russia. Perhaps a better approach would be for an open nuclear war planning process that challenged political leaders to account for the reasons behind their nuclear policies and forced them to describe what would happen if nuclear warfare ever occurred.

Perhaps a better approach would be for an open nuclear war planning process that challenged political leaders to account for the reasons behind their nuclear policies and forced them to describe what would happen if nuclear warfare ever occurred.

It is now an article of faith that a counterforce strategy—that is, the targeting of U.S. nuclear weapons against Russian nuclear and military forces—was more rational and moral than a countervalue strategy that targets urban populations. As we will demonstrate, if the United States mounted a strictly counterforce strike today, withholding attacks on cities and population centers, the casualties would still be in the tens of millions. To put it bluntly, the United States needs to face up to the human realities of nuclear weapons, and the consequences of its bloated nuclear arsenal.

Even if the United States chooses to cause tens of millions of casualties, the government could do it with remarkably few weapons. This truth is obscured in the dogma of counterforce, shielded behind walls of secrecy that deny what horrendous human effects a counterforce strike would create. Honesty about the actual effects of the use of nuclear weapons, whether counterforce or countervalue, should force a reevaluation of what is really necessary to deter Russia, or any other adversary, from believing that it could attack the United States with nuclear weapons and avoid devastating retaliation. That same honesty should then spur action to reduce the number of nuclear weapons to minimal levels. In his May 1, 2001 speech at the National Defense University, President George W. Bush said that, "Today's Russia is not our enemy, but a country in transition with an opportunity to emerge as a great nation, democratic, at peace with itself and its neighbors."[1]

Regardless of the efficacy or capability of missile defenses, it is time to admit that the existing strategic nuclear arsenal of thousands of warheads is an artifact of another day.

It is easy to assert that no plausible threat exists today or can be foreseen to justify maintaining over seven thousand strategic nuclear weapons, a significant portion of which are on hair-trigger alert. It is more difficult to create an analytical framework that offers a reasoned answer to how many weapons and what kind of planning constitutes deterrence. With our nuclear war simulation model, NRDC has attempted to provide that kind of tool, and as we will demonstrate in the report, our model tells us that today's nuclear policy is not the answer.

AN OVERVIEW

In Chapter Two, we provide a brief review of the current nuclear situation, trace the history and evolution of U.S. nuclear war planning, and describe the process by which the SIOP is constructed. In Chapter Three, we describe the NRDC nuclear war simulation model and target database. Chapter Four focuses on a counterforce scenario that we believe is a close approximation of an option in the U.S. SIOP. In Chapter Five, we compare an attack on Russian nuclear forces with an attack on Russian cities, and we calculate the effects of targeting cities with a modest number of nuclear weapons. In Chapter Six, we conclude with a review of our findings and recommend several policy initiatives that we think should be pursued and implemented.

Our fundamental conclusion is that the U.S. nuclear war plan, as it is currently implemented, is a major impediment to further nuclear arms reductions. If deep reductions are to be achieved in the future we believe that there must be a thorough examination and critique of the SIOP planning process and the underlying assumptions that guide it. NRDC supports the reduction, and ultimate elimination of nuclear weapons. The elimination of the SIOP as it is currently defined and practiced will allow immediate reductions of existing forces to considerably lower alert levels, immediately improving safety and stability. The elimination of the SIOP will facilitate implementation of negotiated and unilateral reductions to levels that serve as the departure point for far deeper reductions and eventual elimination.

What does the elimination of the SIOP really mean? First and foremost it means the elimination of the doctrine of counterforce, that is, the elimination of the requirement to attack hundreds of targets at a moment's notice, with high "probabilities of kill" for each target type. Until the United States finds the right construct to eliminate nuclear weapons, it will undoubtedly possess a force of some type. We recommend that it be of minimal size, capable of surviving attack, and able to inflict sufficient levels of damage that are clearly enough to deter any contemplated nuclear attack on the United States. This report will prove that we can meet all of those goals with a surprisingly small number of weapons. The targets in a contingency war plan and the choreography of their execution are of secondary importance. Even this modest force could hold at risk tens of millions of people.

CHAPTER TWO

The Single Integrated Operational Plan and U.S. Nuclear Forces

The Single Integrated Operational Plan (SIOP) is the central U.S. strategic nuclear war plan.[1] First drawn up in 1960, it has gone through many changes over four decades and has evolved into a complex and extremely sophisticated document. Nonetheless, it still retains echoes of its origins in the Cold War.

A BRIEF HISTORY OF THE SIOP

For the first fifteen years of the nuclear era, from 1945 to 1960, U.S. nuclear war planning was a haphazard affair with little or no coordination among the services and widespread duplication of targeting.[2] It took some time after Hiroshima and Nagasaki to institutionalize the operational planning process in the various departments and agencies of the U.S. government. The nuclear war planning process emerged in a time of fast-paced technological change, enormous growth of the nuclear arsenal, improving intelligence capabilities to locate targets in the Soviet Union, intense rivalry among the military services and among the unified and specified commands, all brought to a high boil by the fears, anxieties, and apprehensions of the Cold War.

By the end of the Eisenhower Administration, the question of target planning and its relationship to the roles and missions of various commands demanded the attention of the highest government officials to resolve. In August 1959, the Chairman of the Joint Chiefs of Staff (JCS), General Nathan F. Twining (USAF) prepared a memorandum for Secretary of Defense Neil McElroy proposing that the Strategic Air Command (SAC) be assigned responsibility as an "agent" of the JCS to prepare a national strategic target list and a single integrated operational plan. The proposal stalled as deep divisions within the JCS continued throughout the first half of 1960. In an attempt to resolve the issue, Thomas Gates, McElroy's successor, took the basic outlines of Twining's recommendations to President Eisenhower for a decision.

Eisenhower remarked that he would not "leave his successor with the monstrosity" of the uncoordinated and un-integrated forces that then existed.[3]

In early November 1960, Eisenhower sent his science adviser, George B. Kistiakowsky, to Omaha to examine the existing war plans and procedures. Kistiakowsky presented his findings to the president on November 25. The sheer number of targets, the redundant targeting, and the enormous overkill surprised and horrified the president. There were not going to be any easy answers to the complex problems that confronted planners of nuclear war, then or afterwards. It soon became evident that the "solution" of a single plan might not be the rational instrument to control nuclear planning that Eisenhower had hoped for. Rather it quickly became an engine, generating new force requirements fueled by an ever expanding target list, service rivalry, and demanding operational performance.

In December 1960, after the election but before John Kennedy entered office, the JCS approved the first SIOP for Fiscal Year 1962 (July 1, 1961–June 30, 1962). Known as SIOP-62 it was hastily prepared and basically called for a single plan, under which the United States would launch all of its strategic weapons upon initiation of nuclear war with the Soviet Union.[4] The single target list included military and industrial targets many of which were in Soviet, Chinese and satellite cities. Expected fatalities were estimated at 360 to 525 million people.

The Kennedy administration came into office in January 1961, and immediately rejected SIOP-62 as excessive, and refused much else of Eisenhower's national security policy. Secretary of Defense Robert McNamara initiated a series of studies and projects which resulted in SIOP-63, a plan giving the president a series of options and sub-options, with an emphasis against targeting cities and civilian populations. McNamara explained the new counterforce strategy to Congress in early 1962: "A major mission of the strategic retaliatory forces is to deter war by their capability to destroy the enemy's war-making capabilities."[5] Early on, planners recognized the conundrum of retaliating against nuclear forces and the implications of a first-strike became clear. A former McNamara aide was reported to have said, "There could be no such thing as primary retaliation against military targets after an enemy attack. If you're going to shoot at missiles, you're talking about first strike."[6] It is also true that neither side could ever be sure, then or now, that a counterforce attack would destroy all of the retaliatory capability of the other.

The commitment to counterforce opened the floodgates of service proposals for large budgets and new weapons. In response, McNamara sought to reign in the military through the use of "assured destruction" criteria that set high but limited goals of weapon use. While there was much rhetoric about changes in the declaratory policy of the United States—the one the government publicly presented—the employment or action policy remained fairly intact through the Kennedy and Johnson administrations.

Immediately after the inauguration of President Nixon in January 1970, his national security advisor, Henry Kissinger issued a directive to review the military posture of the United States. The administration wanted to have a greater choice of options rather than just an all out exchange. In the President's foreign policy message to Congress in February, he asked: "Should a President, in the event of a nuclear attack, be left with the single option of ordering the mass destruction of enemy civilians, in the face of the certainty that it would be followed by the mass slaughter of Americans? Should the concept of assured destruction be narrowly defined and should it be the only measure of our ability to deter the variety of threats we may face?"

Four years later, after a laborious process, President Nixon issued National Security Decision Memorandum-242 (NSDM-242), "Planning Nuclear Weapons Employment for Deterrence," on January 17, 1974. The new nuclear doctrine became known as the Schlesinger Doctrine, named for Secretary of Defense James Schlesinger who had a major role in shaping it. At the core of the new guidance was an emphasis on planning limited nuclear employment options. "[O]ptions should be developed in which the level, scope, and duration of violence is limited in a manner which can be clearly and credibly communicated to the enemy." All efforts, political and military, had to be used to control escalation. If escalation cannot be controlled and general war ensues, then limiting damage to "those political, economic, and military resources critical to the continued power and influence of the United States and its allies," and destruction of the enemy's resources must be the paramount objectives of the employment plans. Also singled out for destruction were targets that would deny the enemy the ability to "recover at an early time as a major power." Furthermore, the plans should provide for the "[m]aintenance of survivable strategic forces for protection and coercion during and after major nuclear conflict." NSDM-242 also highlighted the importance of the command, control, and communication system. Plans had to deal with direct attacks on the national command authorities themselves and ensure that they could continue to make decisions and execute appropriate forces throughout all levels of combat.

Schlesinger assumed that the expanded application of the forces would increase the credibility of the U.S. deterrent, and in its extended form, to the NATO allies as well. Critics saw it differently. The guidance contributed to the dangerous developments that were increasing the likelihood of nuclear war. The deployment of highly accurate MIRVed missiles on both sides was leading to greater instability in which each side's forces were more threatening to one another.

Despite these criticisms, NSDM-242 and the corresponding documents led to SIOP-5 that took effect on January 1, 1976. Further refinements of the basic strategic doctrine took place in the Carter administration, with Presidential Directive-59 and the Reagan administrations with NSDD-13.[7]

To accompany the planned nuclear weapons buildup that was proposed in the early years of the Reagan administration, Secretary of Defense Caspar Weinberger provided a lengthy Defense Guidance. The guidance called for U.S. nuclear forces to prepare for nuclear counterattacks against the Soviet Union "over a protracted period."[8] The ruling assumption of the guidance was that in order to deter an aggressive Soviet Union that thought that nuclear wars could be won, the United States would have to believe it as well and create a strategy with the requisite forces to do it. Thus language from the guidance stated, "Should deterrence fail and strategic nuclear war with the USSR occur, the United States must prevail and be able to force the Soviet Union to seek earliest termination of hostilities on terms favorable to the United States." With regard to the employment plans, they had to "assure U.S. strategic nuclear forces could render ineffective the total Soviet (and Soviet-allied) military and political power structure through attacks on political/military leadership and associated control facilities, nuclear and conventional military forces, and industry critical to military power." This meant that our plan had to decapitate the leadership. All in all, waging a nuclear war for a protracted period, being able to accurately hit a wide range of leadership targets, and maintain a "reserve of nuclear forces sufficient for trans- and post-attack protection and coercion" was a very demanding list of what forces were needed in the nuclear war plan. The war plans of the 1980s incorporated these features and while certain aspects have been dropped much of it is retained in the SIOPs of the 1990s and even the most recent ones.

After the disintegration of the Soviet Union and the end of the Cold War, President Clinton's first Secretary of Defense Les Aspin announced plans for a Nuclear Posture Review.[9] Approximately a year later, Secretary of Defense William J. Perry, who had replaced Aspin, announced the results of that review.[10] Unfortunately it was not the fundamental examination that the administration promised and the basic assumptions were left intact.[11]

Butler has said that presidents have only a superficial understanding of nuclear war planning and of the consequences of executing an attack. Furthermore, Congress is powerless to influence national security policy with regard to the SIOP.

Three years later, the Clinton Administration began a process to determine a lower level of strategic nuclear forces that it could agree to in a future START III treaty. Not surprisingly, Pentagon nuclear planners and commanders had the greatest influence on the internal deliberations and results. They argued that a level of 2,500 "accountable" warheads (from the 3,500 in START II) would make it impossible for U.S. Strategic Command (STRATCOM) to comply with the existing national guidance on nuclear employment. In response, the Clinton Administration modified the guidance to accommodate existing war fighting demands at lower levels, without changing the fundamental axioms that characterize the current SIOP. Some fanciful Cold War requirements for the United States to "prevail" in a protracted nuclear war were eliminated, but virtually every other aspect of nuclear war fighting doctrine was retained. The core of the nuclear war plan was basically unchanged, but fewer warheads could be accommodated, given the removal of a portion of Russian nuclear forces, improved weapons reliability and accuracy, and a new flexibility and adaptability in matching warheads with targets.

Despite the end of the Cold War, two features of the SIOP remain intact: it continues to be one of the most secret documents in our government, and it is extraordinarily complex. Retired General George ("Lee") Butler, former commander of Strategic Command, responsible for preparation of the SIOP at the end of the Cold War, said:

> *It was all Alice-in-Wonderland stuff . . . an almost unfathomable million lines of computer software code . . . typically reduced by military briefers to between 60 and 100 slides . . . presented in an hour or so to the handful of senior U.S. officials . . . cleared to hear it.*[12]

Butler has said that presidents have only a superficial understanding of nuclear war planning and of the consequences of executing an attack. Furthermore, Congress is powerless to influence national security policy with regard to the SIOP. Senator Dale Bumpers (D-AR) complained to Secretary of Defense Dick Cheney during the FY 1991 appropriations hearings of the impossibility of Congress discharging its constitutional mandate of oversight in light of the secrecy and complexity of the war plan:

> *I don't see how this Committee can deal . . . with strategic technology and strategic weaponry and know, considering the choices—and that's what we're up against here, we're talking about choices and priorities—how can we do that without knowing what the SIOP is which is being crafted by a bunch of people—not just you and others—but an awful lot of people who never appear before this Subcommittee.*[13]

Certain information about and associated with the SIOP has its own level of classification, designated SIOP-ESI (Extremely Sensitive Information). The SIOP occupies a special place among all of the government's secrets. As one observer noted, "even in sophisticated strategic literature the SIOP is spoken of with reverential, almost Delphic awe."[14]

THE SIOP PLANNING PROCESS

Creating the SIOP follows a clear and precise process. First the president establishes a guidance that lays out concepts, goals, and guidelines. The most current guidance is Presidential Decision Directive-60 (PDD-60), signed by President Clinton in November 1997. Based upon the guidance, the Secretary of Defense produces the Nuclear Weapons Employment Policy, or NUWEP. The NUWEP establishes the basic planning assumptions, attack options, targeting objectives, the types of targets within various categories, targeting constraints, and coordination with theater commanders. It is then sent to the Joint Chiefs of Staff where it is refined into a more detailed and elaborate set of goals and conditions that becomes the Joint Strategic Capabilities Plan (JSCP), Annex C (Nuclear)—a document of approximately 250 pages—which contains targeting and damage criteria for the use of nuclear weapons. The JCS then sends the JSCP to Strategic Command in Omaha, Nebraska where it is transformed into an actual war plan that becomes the Single Integrated Operational Plan. It is at this level that words are converted into a plan of action. As a former Deputy Director of the Joint Strategic Target Planning Staff has written, it is "in the implementation that the true strategy evolves, regardless of what is generated in the political and policy-meeting rooms of any Administration."[15]

Throughout the Cold War, the SIOP focused primarily on the Soviet Union. Today most of the weapons in the war plan still target Russia, but other countries are included as well. The SIOP is not one plan or one option, but a set of plans and a series of options constructed from a single target set contained in the National Target Base (NTB).

The U.S. intelligence community has developed a list of some 150,000–160,000 military targets worldwide. Called the Modified Integrated Database (MIDB) it replaced the Integrated Database (IDB), which in turn replaced the Cold War Target Data Inventory (TDI). Based upon the guidance, USSTRATCOM selects as potential targets for nuclear weapons various subsets of the modified IDB—called the National Target Base (NTB). This National Target Base contained about 16,000 targets in 1985, and declined to 12,500 at the end of the Cold War. According to our sources, as a consequence of President Clinton's guidance, PDD-60, the number of targets in today's National Target Base is closer to 2,500, with some 2,000 of these targets in Russia, 300 to 400 in China, and 100 to 200 located elsewhere.[16]

Clinton's PDD-60 provided new guidelines for targeting U.S. nuclear weapons, replacing National Security Decision Directive-13, signed by President Reagan in 1981.[17] According to Robert G. Bell, then senior director for defense policy at the National Security Council (NSC), PDD-60 "remove[d] from presidential guidance all previous references to being able to wage a protracted nuclear war successfully or to prevail in a nuclear war."[18] The new directive, "nonetheless calls for U.S. war planners to retain long-standing options for nuclear strikes against military and civilian leadership and nuclear forces in Russia," and "the directive's language further allows targeters to broaden the list of sites that might be struck in the unlikely event of a nuclear exchange with China."[19]

The SIOP planning process occurs in a series of stages. The major steps are:

- **Target development**

- **Desired Ground Zero (DGZ) Construction:** Grouping installations into aimpoints for weapon allocation, and compiling the coded aimpoints into the National DGZ List (NDL). DGZs are characterized in terms of time sensitivity, location, hardness, priority, defenses, and damage requirements

- **Assignment:** Includes the following steps:
  - *Weapon Allocation:* Assignment of ICBM and SLBM warheads in an initial strike, and aircraft bombs and cruise missiles in a generated-alert strike or follow-on strike to specific aimpoints
  - *Weapon Application:* Allocation and assignment of specific warheads on specific delivery systems to the DGZ, including setting timing, development of aircraft routes, consideration of defenses, etc.
  - *Timing and Deconfliction:* The choreography of the attacks is analyzed to insure there are no conflicts among warhead detonations and flight plans

- **Reconnaissance Planning**

- **Analysis:**
  - *War Gaming*
  - *Consequences of Execution (C of E) Analysis:* Damage assessments, including physical damage, fatalities, population at risk from prompt and delayed nuclear effects, force attrition, and the degree the plan meets guidance

- **Document Production**

The SIOP planning process traditionally took 14 to 18 months to accomplish (the timeline for SIOP-94 was 67 weeks). A Strategic Planning Study begun in 1993 to analyze the Strategic Warfare Planning System made recommendations to streamline the process to reduce the timeline by as much as two-thirds.

The current SIOPs are named for the fiscal year that they enter into force. Prior to SIOP-93, SIOP naming was based on an alphanumeric system tied to the presidential decision document in effect on the day of plan implementation. The last SIOP plan under this numbering system was designated SIOP-6, Revision H, or SIOP-6H. In FY 1993, the fiscal year numbering system went into effect. The first SIOP under this numbering system was SIOP-93, which was prematurely put in place three months early in June 1992.

During the 1990s, each revised SIOP entered into force at the beginning of the fiscal year (October 1). Accordingly, SIOP-99 entered into force on October 1, 1998, the beginning of FY 1999. If the SIOP requires major revisions more than once a year, the plan is designated by adding a letter to the year (e.g., SIOP-99A).[20] The more formal designation for the current SIOP is USCINC STRAT OPLAN 8044-96, Change 1, November 8, 1999, distributed in April 2000.

THE MAJOR ATTACK OPTIONS

Within the SIOP, there are various options available to the President, who has sole legal authority to launch a nuclear attack. As we understand it, there are four basic counterforce strike options.[21] In the past they were called Major Attack Options (MAOs)-MAO -1, -2, -3, and -4. For the purpose of this NRDC report, we also use the term Major Attack Options for our own simulation, although we acknowledge that the actual MAO and our approximation are different. Also included in the war plan are other options for the use of nuclear weapons at lowers levels. These are termed Limited Nuclear Options (LNO), Regional Nuclear Options (RNO), Directed Planning Options (DPO), and Adaptive Planning Options (APO). Some options differ depending on the alert levels of U.S. and Russian strategic forces. It has been reported that there are about 65 “limited attack options” requiring between two and 120 nuclear warheads.[22] The exact term and the numbers may have changed, but a set of options similar to these exists today. The target countries include Russia, China, North Korea, and presumably other nations. Additional “adaptive” options also have been newly created in the 1990s; these include both major and minor generic nuclear war plans that respond to unforeseen scenarios.

As part of the ongoing evaluation of the SIOP, the U.S. war plan is pitted against a hypothetical Russian counterpart know as the RISOP or Red Integrated Strategic Offensive Plan. Like the SIOP, there is a RISOP produced each fiscal year. The SIOP and RISOP engage in simulated combat using sophisticated computers and programs to determine what might happen. Recent data about population and weather as well as military forces are important elements of the game. Analysis of the results and consequences of the interaction are studied to discover what weaknesses and stresses there are in the SIOP so that the real SIOP can be enhanced. In an April 1999

USSTRATCOM briefing, the Red countries included Russia, China, North Korea, Iran, Iraq, Syria, and Libya.[23] Almost three-dozen countries made up the Blue/Gray team led by the U.S.[24]

In the United States, the JCS requirements dictate the number of nuclear weapons in the active inventory. These requirements state that the nuclear forces must be prepared to execute the full range of nuclear attack options outlined in the President's national nuclear guidance, and detailed in ancillary documents of the Secretary of Defense, JCS, and unified military commands. These requirements are defined by the ability of the forces to carry out a series of major and minor attack options. The Major Attack Option-1 (MAO-1) is the most demanding major counterforce attack option available to the President, should he order the use of nuclear weapons against Russian nuclear forces. This attack calls for the use of over one thousand U.S. nuclear warheads targeted against Russian nuclear forces, all of the Russian ICBM silos, road-mobile and rail-mobile ICBMs, submarine bases, primary airfields, nuclear-warhead storage facilities, the nuclear weapon design and production complex, and critical command and control facilities. MAO-1 spares the political leadership and a portion of the military leadership—to allow for intra-war negotiations—and to avoid, as much as possible, cities and urban areas. Under SIOP-99, the number of individual targets in MAO-1 is thought to be in the 1,000–1,200 range, or about one-third of the total number in the current NTB.[25] The number of nuclear weapons required to exercise this option would be somewhat greater.

Despite significant reductions in the number of nuclear warheads that began in the mid-1980s, the process of planning for large-scale nuclear war against Russia remains essentially unchanged.

Other major attack options are even more extensive, adding additional targets up to, and including a full-scale attack against Russian nuclear forces, leadership, and the economic and energy production infrastructures. MAO-2 includes the basic counterforce option (MAO-1), plus other military targets, such as conventional ground forces and secondary airfields. MAO-3 adds leadership, and MAO-4 includes economic targets, which through nodal analysis have been reduced from hundreds of factories to those concerned with weapons assembly, and energy production and distribution. The actual targets and the details of the targeting plans developed by USSTRATCOM remain highly classified.

The introduction of each revised SIOP is at once entirely routine and, in this day and age, utterly remarkable. Despite significant reductions in the number of nuclear warheads that began in the mid-1980s, the START arms control negotiations and treaties, the official Russian-American cooperative programs, the missile "detargeting" agreements, and other measures to reduce the likelihood of nuclear war, the process of planning for large-scale nuclear war against Russia remains essentially unchanged.

Several recent statements from civilian and military officials reflect this continuity. In May 2000, the Senate Armed Services Committee held a hearing to address nuclear war planning for the first time since the end of the Cold War. Several Clinton administration witnesses defended the status quo. For example Under Secretary of Defense for Policy Walter B. Slocombe said:

> *Our overall nuclear employment policy [states that] the United States forces must be capable of and be seen to be capable of holding at risk those critical assets and capabilities that a potential adversary most values.*[26]

At the same hearing, Admiral Richard Mies, Commander in Chief of U.S. Strategic Command, responsible for all strategic nuclear forces and preparation of the SIOP, said:

> *Our force structure needs to be robust, flexible and credible enough to meet the worst threats we can reasonably postulate. Our nation must always maintain the ability to convince potential aggressors to choose peace rather than war, restraint rather than escalation, and termination rather than conflict continuation.*

More recently, the Chiefs have noted they are "concerned about arms reductions that reduce the flexibility in strategic deterrence and put at risk maintaining all three legs of the Triad [i.e., ICBMs, SLBMs, and bombers]."[27]

ARMAMENT DEMANDS OF THE SIOP

Despite the fact that the Cold War ended more than a decade ago, to implement their respective war plans today the United States and Russia continue:

- To maintain enormous numbers of deployed nuclear weapons
- To maintain thousands of nuclear warheads on hair-trigger alert
- To retain several thousand non-deployed warheads as a "hedge" to redeploy in a future arsenal
- To store huge inventories of nuclear warhead components

The United States currently maintains an active inventory of over 7,000 strategic nuclear warheads, 1,600 non-strategic warheads, and another 2,000 warheads in an inactive or hedge status.

The United States currently maintains an active inventory of over 7,000 strategic nuclear warheads, 1,600 non-strategic warheads, and another 2,000 warheads in an inactive or hedge status. The Department of Energy (DOE) keeps in storage over 12,000 intact plutonium "pits" from nuclear warheads, and an estimated 5,000–6,000 "canned subassemblies"—the thermonuclear component or secondary stage of a two-stage nuclear weapon. Though intercontinental bombers were removed from day-to-day alert in 1991, land-based missiles and strategic submarines maintain a Cold War level of operation.

In an effort to keep pace with the U.S. and to respond to its existing war plan, Russia has kept a sizable arsenal of its own. Russian nuclear forces include some 10,000 active nuclear warheads—about 6,000 strategic and 4,000 non-strategic. Overall, the number of Russian warheads is thought to be around 20,000, with 10,000 of those inactive, mostly non-strategic types (e.g., short-range missiles, naval weapons, or air-delivered weapons for short-range aircraft). These short-range, non-strategic weapons dominate a Russian "hedge," if it exists. Russian heavy bomber forces pale in comparison to U.S. forces, and submarine patrols are infrequent. The land-based missile force remains the core of Russian strategic capabilities, and at a high level of alert, is presumably able to attack with some 3,000 warheads at a moment's notice.

In most respects, strategic nuclear forces are postured much like they were during the Cold War. The Presidents of the United States and Russia each retain the capability to launch nuclear weapons against each other's country in a matter of minutes using land-based and sea-based ballistic missiles and strategic bombers (Russian strategic submarine missiles could be launched from pier-side or local waters). A military aide to each president, never more than a few steps away, carries a briefcase—in the United States it is known as the "football," in Russia as the *cheget*—containing descriptions and launch procedures for a wide range of nuclear attack options contained in the SIOP and the Russian equivalent. The options are believed to range from the use of a few weapons to the unleashing of thousands of them.

As U.S.-Soviet relations warmed at the end of the Cold War, the trend was to make these war plans more "rational" and reduce forces. Yet despite improvements, in U.S.-Russian relations, reductions have stalled and nuclear arsenals remain enormous, with thousands of intercontinental weapons on instant alert. The Strategic Arms Reduction Treaty (START) process has been deadlocked for some time. The United States and Russia have agreed to negotiate to levels of 2,000 to 2,500 "accountable warheads" under START III, but no formal negotiations have occurred. In November 2000, Russia said it was willing to consider 1,500 strategic nuclear warheads for each side, and Russian President Vladimir Putin has indicated that Russia was ready to consider even lower levels than this. President Bush has expressed his commitment to quickly reduce the level of U.S. forces—what he has called "relics of dead conflicts"—to lower levels "consistent with our national security needs."[28]

THE SIOP AND DETERRENCE

National security needs in the past have always meant fealty to the secret dictates of the SIOP, and hence the retention of large numbers of weapons for counterforce nuclear war fighting. The SIOP has long been premised on maintaining the perception of a credible U.S. capability to threaten first-use of nuclear weapons to stave off a conventional military defeat or to terminate a regional conflict on terms favorable to the United States and its allies. Sustaining the credibility of this threat has inexorably generated military requirements to attack preemptively any and all Soviet/Russian nuclear forces that might be employed in retaliation against such limited U.S. nuclear strikes, up to and including a massive preemptive strike on the entire Soviet/Russian nuclear force and target base.

There are inherent discrepancies between the nuclear declaratory policy and the nuclear employment policy of most countries, and the United States is no exception. U.S. declaratory policy is what officials say publicly about how nuclear weapons would be used. During the Cold War, official public statements usually suggested that the United States would employ its strategic nuclear arsenal only in retaliation against a Soviet nuclear "first-strike." But this rationale poses a logical disconnect that suggests an unsettling theory. If the Russians attacked first, there would be little left to hit in retaliating against their nuclear forces, and even less by the time the U.S. "retaliatory" attack arrived at its targets. Many Russian missile silos would be empty, submarines would be at sea, and bombers would be dispersed to airfields or in the air. Ineluctably, the logic of nuclear war planning demands that options exist to fire first. Thus the U.S. President retains a first-strike option, regardless of whether he has any such intention or not. The Soviet Union was faced with a similar dilemma and must have come to similar conclusions. As a consequence, therefore, both sides' nuclear deterrent strategies have "required" large and highly alert nuclear arsenals to execute preemptive strike options.

Another credibility gap exists within the U.S. government between the secret dictates of the SIOP (and other non-strategic nuclear war plans), and what an American president might order in "defense" of American and allied interests. After the use of just two nuclear weapons at Hiroshima and Nagasaki in World War II, nuclear first-strikes large or small have not been within the moral choices of American presidents, even when American or allied forces have been on the verge of defeat on the conventional battlefield. Proponents of maintaining such a threatening "first-use" nuclear deterrent posture argue that the executive's long record of moral and political resistance to ordering nuclear first-strikes under any circumstances does not negate the nuclear war plan. Instead, they argue that the *mere existence* of such threatening preemptive capabilities imposes a high degree of caution on any potential adversaries' conduct.

Whether or not this nuclear-war fighting theory of deterrence has any merit, all sides agree that the geopolitical confrontation that spawned the growth of nuclear arsenals and the creation of exotic war plans has faded into history. The current SIOP truly is a Cold War relic of an earlier era. The strategic rationale for maintaining a capability for graduated nuclear attacks and massive preemptive strikes on Russian nuclear forces has evaporated. The "expansionist" and hostile Soviet "evil empire," bent on conquest and subversion in Western Europe and elsewhere, no longer exists, and thus "extended" deterrence outlined in the SIOP is no longer needed as well.

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CHAPTER THREE

The NRDC Nuclear War Simulation Model

The NRDC Nuclear Program has developed software and databases that provide new capabilities to analyze the scale and consequences of nuclear violence. During the Cold War, a number of individuals and institutions published studies and reports about nuclear conflict, creating a reference set of calculations and formulas in the process. We have revisited some of these earlier efforts with vastly improved technological and computing resources and with greater access to once secret information. NRDC's nuclear war simulation model can now provide a glimpse of the war planning process.

The NRDC Nuclear War Simulation Model relies on a collection of nuclear weapon effects formulas and several sets of input data, including:

- Characteristics of the attacking nuclear weapons or forces
- Parameters of the attacked targets, including coordinates, and vulnerability
- Geographic and demographic data for the attacked country
- Meteorological data, particularly wind data for fallout calculations

These nuclear weapons effects formulas and input data are integrated into a Geographic Information System (GIS) called ArcView. This commercial software package allows the user to display any data that have associated spatial coordinates, such as latitude and longitude. The user can integrate into ArcView other computer models, e.g., the nuclear weapon effects, to perform additional calculations. ArcView is then able to further analyze and display the results of the calculations. NRDC has customized ArcView to facilitate management of the input and output data, to perform the nuclear weapon effects calculations, and to reduce the time required for the calculations.

Below we review the components of NRDC's nuclear conflict software and database suite.

CHARACTERISTICS OF THE ATTACKING NUCLEAR FORCES

Our model describes the nuclear arsenal of the attacking nation—in this case the United States—in terms of:

▶ The type and number of nuclear warheads and their nuclear weapon delivery systems
▶ The various levels of alert at which the nuclear force operates
▶ The yield or yield options of the warhead, and the fraction of the yield produced by fission, for the different design types (e.g., gun-type fission, boosted-fission implosion, high-yield thermonuclear)
▶ The performance features of the several kinds of delivery systems (e.g., MX ICBMs, Trident D-5 SLBMs, B52H bombers) measured by range, flight time, accuracy, and reliability

To gain a clear picture of what a U.S. nuclear attack on Russia would look like, NRDC started by analyzing the characteristics of the U.S. arsenal. There are currently seven kinds of delivery vehicles and nine warhead types in the U.S. arsenal.[1] The 1,054 U.S. strategic delivery vehicles (ICBMs, SLBMs and strategic bombers) and approximately 7,200 operational strategic nuclear warheads are deployed at four alert levels: "Launch Ready," "Generated I," "Generated II," and "Total Forces." The four alert levels are distinguished by how many delivery vehicles are fully deployed, and how quickly they are able to fire their weapons (see Table 3.1). Launch Ready refers to the day-to-day alert level of U.S. nuclear forces that includes most (95 percent) of the ICBMs and four SSBNs at sea within range of their targets. The second level, Generated I, would add five SSBNs. Generated II would indicate a serious crisis where six more SSBNs and 64 bombers would be placed on alert. At this point, approximately 90 percent of the total forces would be on alert. It would take considerable effort to generate the last ten percent—the entire force including all 550 ICBMs, 18 SSBNs, 16 B2s, and 56 B52Hs—to full alert status, though theoretically it could be done. The basic characteristics of the nine types of nuclear warheads in the current U.S. arsenal are presented in Table 3.2. The 550 U.S. ICBM silos, two strategic submarine bases, and three strategic bomber bases are depicted in Figure 3.1.

In addition to listing the various nuclear warheads, we also analyzed each weapon's fission fraction. Assumptions about fission fraction play an important role in calculating the initial radiation produced in a nuclear explosion and the amount of fallout. Here we assume the fission fraction of all thermonuclear weapons at full yield is between 50 and 80 percent. For low-yield options of the bomber-delivered weapons, we assume the fission fraction is 100 percent. The fission fraction may be

TABLE 3.1
Summary Data for the Four Alert Levels of the Current U.S. Strategic Arsenal

Alert Level	% ICBMs on Alert	% SLBMs on Alert	% Bombers on Alert	Total # Delivery Vehicles	Total # Warheads
Launch Ready	95	22	0	618	2,668
Generated I	95	50	0	738	3,628
Generated II	99	78	90	944	6,238
Total Forces	100	100	100	1,054	7,206

TABLE 3.2
Characteristics of Delivery Vehicles and Nuclear Warhead Types in the U.S. Arsenal

Warhead	Total Number	Delivery Vehicle Type	Delivery Vehicle	Accuracy (CEP, m)	Yield(s) (kt)	Fission Fraction(s) (%)
W62	600	ICBM	MM III/Mk-12	183	170	50
W78	900	ICBM	MM III/Mk-12A	183	335	50
W87-0	500	ICBM	MX/Peacekeeper/Mk-21	91	300	50
W76	3,072	SLBM SLBM	Trident I C-4/Mk-4; Trident II D-5/Mk-5	229-500; 130-183	100	50
W88	384	SLBM	Trident II D-5/Mk-5	130-183	450-475	50
B61-7	300	Bomber Bomber	B2 and B52 Bombers	0	0.3, 5, 10, 80, 350	100, 100, 100, 50, 50
B61-11	50	Bomber	B2 Bomber	0	0.3, 5, 10, 80, 350	100, 100, 100, 50, 50
W80-1	800	Bomber	B52 Bomber/Air Launched Cruise Missile	0	0.3, 5, 10, 80, 150	100, 100, 100, 50, 50
B83	600	Bomber	B2 and B52 Bombers	0	1000	50

varied in the NRDC model. Accuracy is expressed in circular error probable (CEP), which is defined as the radius of a circle centered on the desired target within which on average half the warheads will fall. The government has classified its estimates of the CEP of various delivery systems. We drew our estimates from ones generally used in unclassified studies. We have used them to compute the probability of damaging or destroying specific target types. We currently plan in a later phase of this project to address the complex choreography of thousands of nuclear weapons

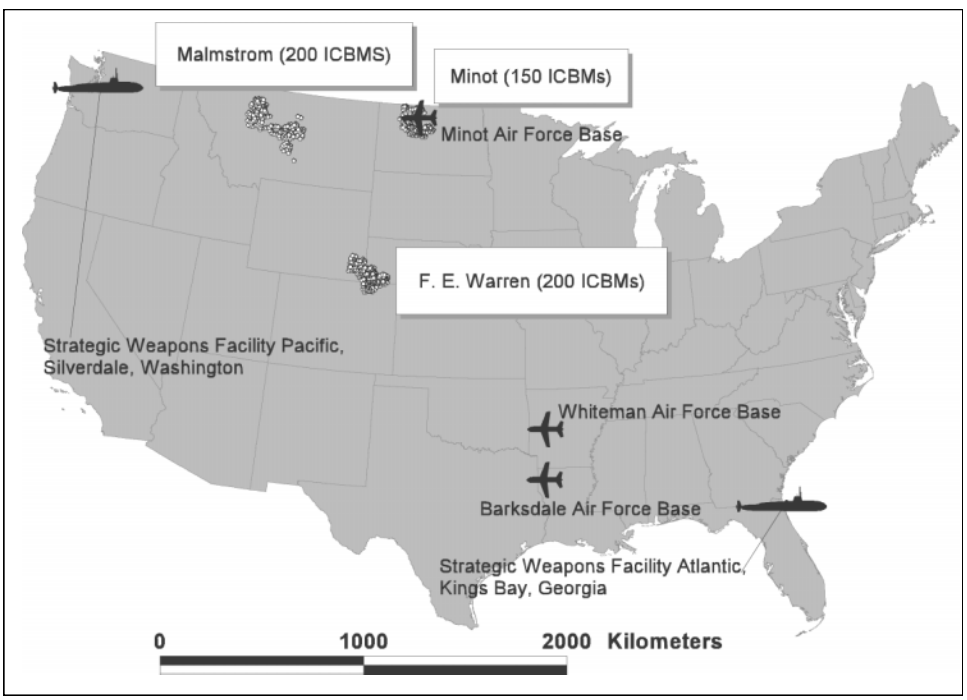


FIGURE 3.1
Locations of U.S. Nuclear Forces
This map shows: the 550 U.S. ICBM missile silos deployed at F.E.Warren (150 Minuteman III and 50 MX missiles distributed over approximately 22,000 square kilometers (km^2) at the intersection of Colorado, Wyoming, and Nebraska); Minot (150 Minuteman III missiles distributed over approximately 16,000 km^2 in North Dakota); and Malmstrom (200 Minuteman III missiles distributed over approximately 30,000 km^2 in Montana); three U.S. air force bases where strategic bombers are deployed; and the two U.S. naval strategic-weapons facilities.

launched at their targets, including calculations of warhead trajectories and flight times, footprint size, and fratricide based on the location and timing of the launches (as well as bomber flight paths and refueling points).

In the NRDC nuclear war simulation model, the user may assign attacking warheads to targets with respect to a constraint on the number of available warheads of each type. For example, the user may opt to construct an attack based on current U.S. launch-ready forces only, or with START II, START III, 1,000-warhead and 500-warhead forces at any of the four alert levels. We included the constraint option in our model to see what the capabilities are and the extent of damage that results for various sized forces.

TARGET DATA

As discussed in Chapter Two, USSTRATCOM has selected a set of potential nuclear weapon targets, known as the National Target Base (NTB), from a larger target list called the Modified Integrated Database (MIDB). We believe that the number of targets in the NTB is currently around 2,500, with about 2,000 of them in Russia, 300 to 400 in China, and 100 to 200 elsewhere.[2]

We believe that the number of targets in the National Target Base is currently around 2,500, with about 2,000 of them in Russia, 300 to 400 in China, and 100 to 200 elsewhere.

USSTRATCOM also maintains the Joint Resources Assessment Database System (JRADS), a comprehensive database used to facilitate strategic war planning. JRADS contains worldwide population data, industrial worth, and information about U.S. and non-U.S. installations. It is the U.S. government's central repository of accurate population data and facility information and is widely used throughout their departments and agencies.[3]

NRDC is in the process of assembling from public sources its own series of target databases to serve the NRDC nuclear war simulation model. Instead of compiling a single global database, we have six databases covering six geographic regions:

- Russian targets
- U.S. targets
- European, North African and Middle Eastern targets
- Chinese targets
- East Asian targets (excluding China)
- South Asian targets (India and Pakistan)

Of the six, our Russian database is the most fully developed: it contains almost 7,000 sites in Russia. We have sought to include the types most likely to be in the National Target Base. It should be emphasized that our databases do not purport to be a replication of the NTB. Our suite of databases might be thought of as a hybrid, containing some targets not in the NTB, but far fewer than those in the MIDB. For instance, our database contains almost twice as many targets as the NTB. Some of the differences in the numbers can be readily explained. For example, for historical purposes we have included many closed facilities, including dismantled missile silos. For completeness, we have sought to include all airfields, even small civilian ones, since we are not always confident whether a specific airfield is civilian, military, or dual purpose. We have included all known power plants with a capacity greater than about one megawatt-electric (MWe). Also included are all of the military sites identified in the data exchanges related to the START and Conventional Forces in Europe (CFE) treaties. We lack knowledge in certain areas, such as the locations of important leadership sites, communication nodes, and industrial facilities.

The availability of a data set larger than the NTB permits us not only to identify likely targets, but to have a better understanding of which sites are not included under various attack options and which are included in the collateral damage resulting from the selection of nearby higher priority targets.

USSTRATCOM, in the JRADS database, uses a hierarchical functional classification code structure to categorize facilities and targets.[4] It appears that the same classification coding system is used in the MIDB and in the NTB.[5] While we still do not know all of the facility types and classification code numbers used in the U.S. government databases, many of these are known and are reproduced in Appendix A.

The NRDC target database uses a more simplified classification scheme. All targets are first grouped under four broad "Target Classes:"

- Nuclear forces (NF)
- Leadership-including command, control and communication (L-C3)
- Other military targets (conventional military forces) (OMT)
- War support industry ("urban/industrial") (WSI)

We break these four down even further into "target categories" and "target types." The classification scheme used in the NRDC target databases is provided in Appendix C.

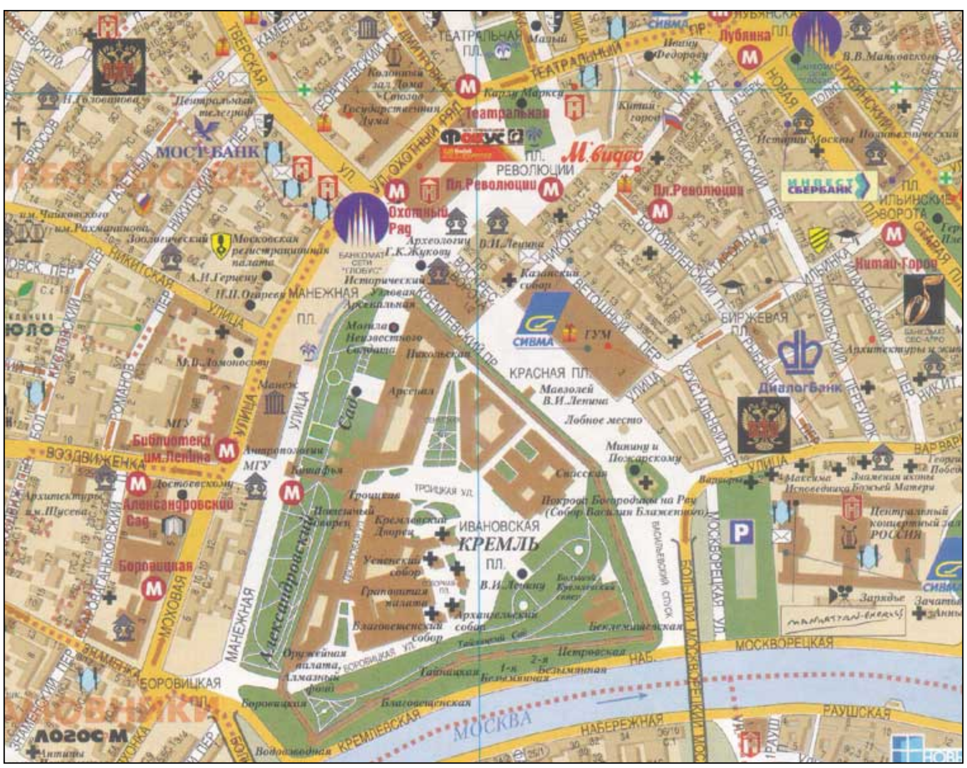


FIGURE 3.2
A Geo-referenced Moscow Street Atlas
This geo-referenced portion shows the Kremlin and the Duma (Russian lower house of parliament). This street atlas was geo-referenced by aligning it with a larger-scale street grid that in turn was aligned to the corresponding U.S. military JOG based on features such as the intersection of roads, railroads, rivers, and streams. Source: Atlas-Moskva, April 1998.

We have located the coordinates of the vast majority of targets we have identified. Target locations are recorded to the nearest second of latitude and longitude where the data is available. In some cases, we know the coordinates to the nearest minute, in others only by the name of the city or town where a facility is located. The coordinates of cities and towns are easily obtained from the National Imagery and Mapping Agency's (NIMA) publicly available database or from U.S. government maps.[6] We found three series of government maps particularly useful: Operational Navigation Chart (ONC) 1:1,000,000 scale; Aeronautical Charts 1:500,000 scale; and Joint Operations Graphic (JOG) 1:250,000 scale. For large cities, unless a precise address or street map is available, the uncertainty in location can be 15 minutes or more. Moscow and St. Petersburg street maps have been geo-referenced as part of this project and thus if we know the street address we can locate the coordinates to within about 100 meters. Figure 3.2 shows a portion of our geo-referenced Moscow street atlas in the vicinity of the Kremlin. Table 3.3 converts minutes and seconds to meters as a function of latitude in order to put into perspective the precision of the NRDC database coordinates.[7]

Satellite imagery provides a valuable tool for locating and understanding the layout of such major targets in Russia as the closed nuclear cities, naval bases, nuclear-weapon storage facilities, and airfields. Public availability of high-resolution satellite imagery creates a fundamentally new opportunity for non-governmental organizations to research arms control information. Increasingly, these organizations, such as the Federation of American Scientists, are using historical satellite imagery or commercially available imagery of military facilities in their work.[8] The two main sources of satellite imagery used in the NRDC project are the U.S. government's images from the Corona program (which are available for purchase from the National Archives in College Park, Maryland) and contemporary film footage taken by the Ikonos satellite (licensed commercially through the Space Imaging Corporation).

The Corona satellite photography program began in August 1960 and continued until May 1972, and involved over 100 missions.[9] The program provided extensive (but not continuous) coverage of nuclear and other military sites in Russia.[10] The first Corona camera had a resolution of about 40 feet.[11] By 1963 improved cameras for the KH-2 and KH-3, achieved a resolution of 10 feet.[12] By 1967, the J-3 camera of the KH-4B was able to photograph with a resolution of five feet,[13] continuing until 1972.[14] Figure 3.3 shows a Corona image of the Nenoksa SLBM test facility west of the Russian city of Arkhangelsk.

Archived, one-meter resolution images taken by the Ikonos satellite may be browsed in a 16-meter resolution format at the Space Imaging Corporation's Internet site (www.spaceimaging.com). At the base price for archived or new Ikonos imagery, the Space Imaging Corporation will geo-reference its images to within an accuracy of ± 50 meters. For a significantly higher price the geo-referencing accuracy can be increased to ± 12 meters. Figure 3.4 is an Ikonos image of the Russian Rybachiy nuclear submarine base near the city of Petropavlovsk-Kamchatskiy in the Russian Far East. Though the image is in the 16-meter resolution format, features such as piers and buildings are clearly visible.

We derived the information for the NRDC Russian target database from a wide variety of sources. Data on strategic nuclear forces derives primarily from the "START Treaty Memorandum of Understanding Data" exchanges. The coordinates of missile silos, launch-control centers and bases, SSBN bases, strategic-bomber bases, missile-storage facilities, and missile- and bomber-production and elimination facilities to the nearest minute of latitude and longitude are found in Annex 1 of the START Treaty data exchange. Thus, the locations are known to within ± 0.5 minutes (± 927 meters, or less). Some of these sites can be identified on more recent JOGs. On these 1:250,000 scale maps, coordinates can be recorded with a precision of about ± 15 seconds (± 460 meters, or less). The "START Treaty Memorandum of Understanding Data" is updated biannually (31 January and 1 July), and is publicly available within 90 days. The MOU includes the number of deployed and non-deployed ICBMs, ICBM launchers, SSBNs, SLBMs, strategic bombers, and production, storage, and elimination facilities.

The principal source of information about conventional military force deployments west of the Ural Mountains (for the Moscow, Northern, Volga, and North Caucasus Military Districts) is provided in the Conventional Forces in Europe Treaty (CFE) data exchange. There is little publicly available information about Russian conventional force deployments in the Ural, Siberian, Transbaikal, and Far East Military Districts. The CFE Treaty data exchange provides coordinates of military units (e.g., regiments and divisions) to the nearest 10 seconds (i.e., ± 5 seconds or about ± 150 meters or less) and data on the numbers of military personnel, combat aircraft, helicopters, tanks, armored vehicles, and artillery in the units.

The NRDC target database has drawn upon numerous additional sources including:

- The six editions of the U.S. Department of Defense's *Soviet Military Power* (1981–1987), and *Military Forces in Transition* (1991), which provide useful data on the deployment of conventional and strategic Russian forces.
- The Digital Chart of the World (a commercial product of ESRI Corporation), the NIMA public database, the ONC and JOG maps, Aeroflot commercial flight timetables, various DOD Flight Information Publications, and the maps in *Soviet Military Power* have been used to determine locations and characteristics of Russian airfields.
- NRDC publications about the Soviet nuclear-weapons production complex.[15] A recent NRDC report by Oleg A. Bukharin of Princeton University analyzes Corona images of the Russian, closed nuclear cities.[16]

TABLE 3.3
Conversion of Minutes and Seconds to Meters as a Function of Latitude

At Latitude	45°	55°	65°	75°
1 min latitude ≈	1,852 m	1,850 m	1,848 m	1,846 m
1 sec latitude ≈	31 m	31 m	31 m	31 m
1 min longitude ≈	1,312 m	1,064 m	784 m	480 m
1 sec longitude ≈	22 m	18 m	13 m	8 m

FIGURE 3.3
Corona Satellite Image of the Nenoksa SLBM Test-Launch Facility
Near Arkhangelsk in northern Russia, acquired during mission 1115-2 on September 18, 1971. Source: Joshua Handler, Princeton University.

▸ Exchanges and research programs funded under the DOD's Cooperative Threat Reduction (Nunn-Lugar) programs, various Department of Energy (DOE) initiatives in Russia, and the International Science and Technology Center's research programs.
▸ Russian power plant data from three sources. First a set of four maps commercially available from East View Cartographic, Minneapolis, Minnesota shows the name, type, size, and approximate location of all power plants larger than about one megawatt-electric. Second, a power plant database (without locations), from McGraw-Hill Publications. And third, the JOG and ONC maps, which indicate vertical obstructions, smokestacks, and power lines.
▸ Two CD-ROMs published by the International Telecommunications Union (Union Internationale des Télécommmunications), Geneva, which provide information about Russian radio transmitters, and satellite earth station. Since the coordinates are not always accurate, we have attempted to improve the accuracy by using the ONC and JOG maps.
▸ Bellona Foundation reports (www.bellona.no), which provide information on the Russian Northern Fleet.[17]
▸ Joshua Handler's research on Russian naval bases and nuclear-weapon storage sites.[18]
▸ The growing volume of data that identifies the names and addresses of Russian commercial firms marketing military technology, thus providing information about the War Support Industry targets.

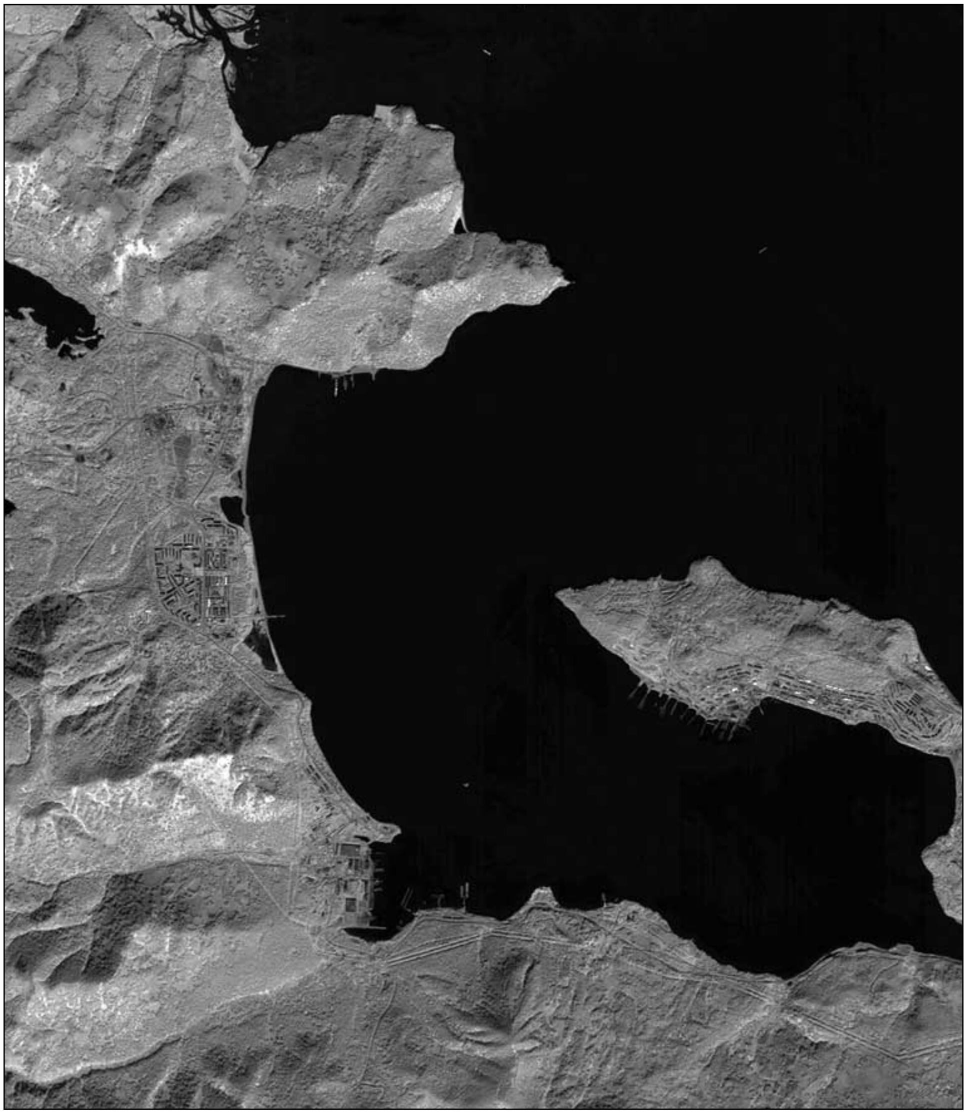


FIGURE 3.4
Ikonos Satellite Image of the Russian Rybachiy Nuclear Submarine Base
This image shows the base near the city of Petropavlovsk-Kamchatskiy in the Russian Far East. Acquired on September 6, 2000. Source: spaceimaging.com.

A unique identification number and name identify each target in NRDC's six databases. Each target record also includes the coordinates, a description of the target, and additional fields of data. The Russian database has more than 90 data fields (see Appendix B).

THE EFFECTS OF NUCLEAR EXPLOSIONS

In order to fully analyze nuclear war plans, we have sought to understand the complex effects of nuclear explosions. With this initial version of the NRDC nuclear war simulation model, we have been able to quickly and accurately calculate the principal effects of a nuclear explosion for a sub-surface burst, a surface burst, and an air burst using a personal computer. We then used these calculations to determine the probability of damaging specific target types, and to compute civilian casualties and the radioactive contamination of the environment.

TABLE 3.4
Nuclear Weapon Types and Their Associated Yield Ranges

Type	Description	Yield Range (kt)
1	Gun-assembly fission weapon	0.1 to a few tens
2	Boosted or unboosted fission implosion weapon, old design	1 to a few tens
3	Unboosted fission implosion weapon, contemporary design	less than 1
4	Boosted fission implosion weapon, contemporary design	1 to a few tens
5	Boosted fission implosion weapon, modern design	1 to a few tens
6	Unboosted fission implosion	less than 1
7	Boosted fission implosion	1 to 10
8	Thermonuclear having a single yield	A few tens to 5000
9	Thermonuclear having multiple yields; high-yield option	100 to 500
10	Thermonuclear having multiple yields; low-yield option	A few tens
11	Tactical (clean) thermonuclear	A few tens to a few hundreds
12	Thermonuclear, very high yield	greater than 5000
13	Enhanced radiation	not given

Glasstone and Dolan describe the general effects of nuclear explosions in the standard reference work, *The Effects of Nuclear Weapons*.[19] We found useful supplementary information in: the declassified 1972 Defense Nuclear Agency *Effects Manual Number 1*,[20] the Defense Nuclear Agency computer codes BLAST[21] and WE,[22] and the Lawrence Livermore National Laboratory computer code KDFOC3.[23] We provide in Appendix D an NRDC compilation of formulas based on these sources for the nuclear explosion blast wave parameters, crater dimensions, thermal radiation (heat) flux, and initial radiation dose.

The following four sections on nuclear weapons effects record our journey and highlight some of the interesting things that we have learned. The first section provides an overview of the thirteen basic types of nuclear weapons noting how they differ in their effects. In the next section, we draw from the historical record of Hiroshima and Nagasaki to discuss the deaths and injuries that could result from the use of high-yield nuclear weapons. In the third section, we examine the nuclear fallout models based upon a Lawrence Livermore computer code, and we compare and contrast it with data from U.S. atmospheric tests conducted in Nevada and the Pacific. The fourth section introduces the U.S. physical vulnerability system whereby damage expectancies or kill probabilities are calculated for specific classes of targets.

Thirteen Nuclear Weapon Types

Scientific and engineering knowledge of nuclear explosives has evolved for more than a half century and continues to develop in the United States through the Science-Based Stockpile Stewardship Program. The first two nuclear weapon types were plutonium-implosion and uranium gun-type fission designs—the "Fat Man" and "Little Boy" bombs dropped on Japan in 1945. Subsequent advances increased the efficient use of fissile material, reduced the weight of a nuclear weapon for a given explosive yield, incorporated fusion reactions in the explosion, provided for multiple-yield options in a single weapon, and enhanced the initial radiation output of the bomb with respect to blast. In a 1984 report, the U.S. Defense Nuclear Agency listed 13 nuclear weapon designs and their yield-range (see Table 3.4). It is unclear what the differences are among "old design," "contemporary design," and "modern design" for types 2–5.

The nuclear weapons effect of initial radiation refers to the radiation released up to one minute after the explosion.[24] It has three components: the prompt neutrons (emitted in the course of the fission and/or fusion reactions), the gamma rays from the decay of fission products, and the secondary gamma rays produced when the prompt neutrons interact with atoms of the air or ground. The initial radiation produced in a nuclear explosion will vary according to the type of nuclear weapon. For example, the fusion reactions occurring in the explosion of a thermonuclear weapon produce high-energy neutrons (in the range 10–15 MeV) that are not produced in the explosion of a fission weapon. To give another example, neutrons are absorbed and scattered when they pass through a nuclear weapon's absorbing materials, e.g. the tamper, chemical high explosive and casing. A weapon type with relatively thin absorbing materials, for example the "Little Boy" gun-assembly fission design (type 1 in Table 3.4), will produce a higher dose of radiation to human tissue at a given distance from the explosion than a weapon type of the same yield but with relatively thick absorbing materials, like the "Fat Man" fission implosion weapon (type 2 in Table 3.4).[25]

To show how the effects of initial radiation depend on design, Figure 3.5 compares the prompt neutron output at one-kiloton explosive yield for four types of nuclear weapons. The lowest initial-radiation dose occurs in the old fission implosion design. The dose from a gun-assembly or a thermonuclear explosion is two to three times higher, and for an enhanced-radiation weapon (or neutron bomb)

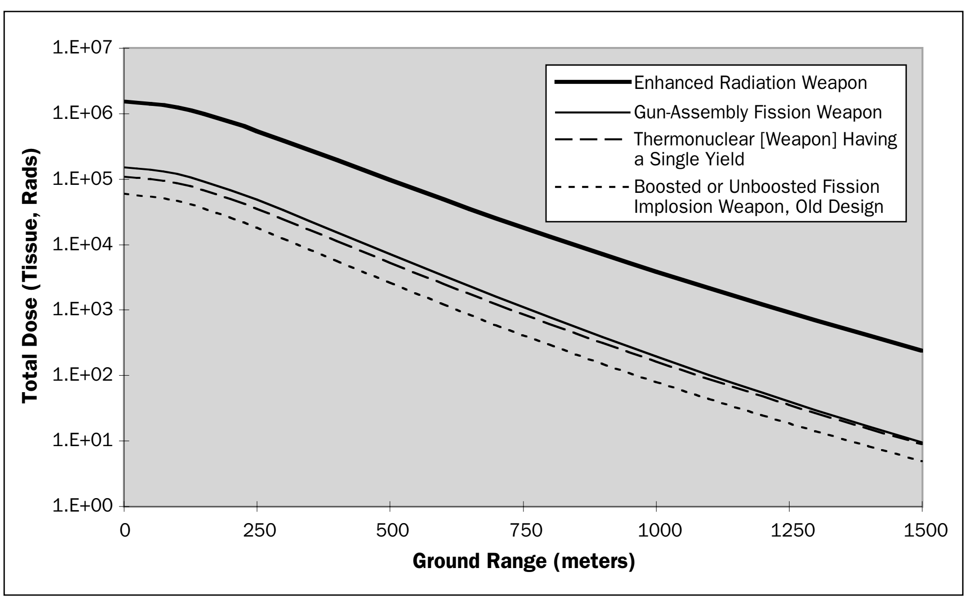


FIGURE 3.5
Initial Radiation Output of Four Nuclear Weapon Designs
In these calculations, we used yields of one kiloton, heights of burst of 238 meters, and mean sea-level air density. For the thermonuclear weapon, a fission fraction of 50 percent was used and for the enhanced radiation weapon, a fission fraction of 75 percent was used.

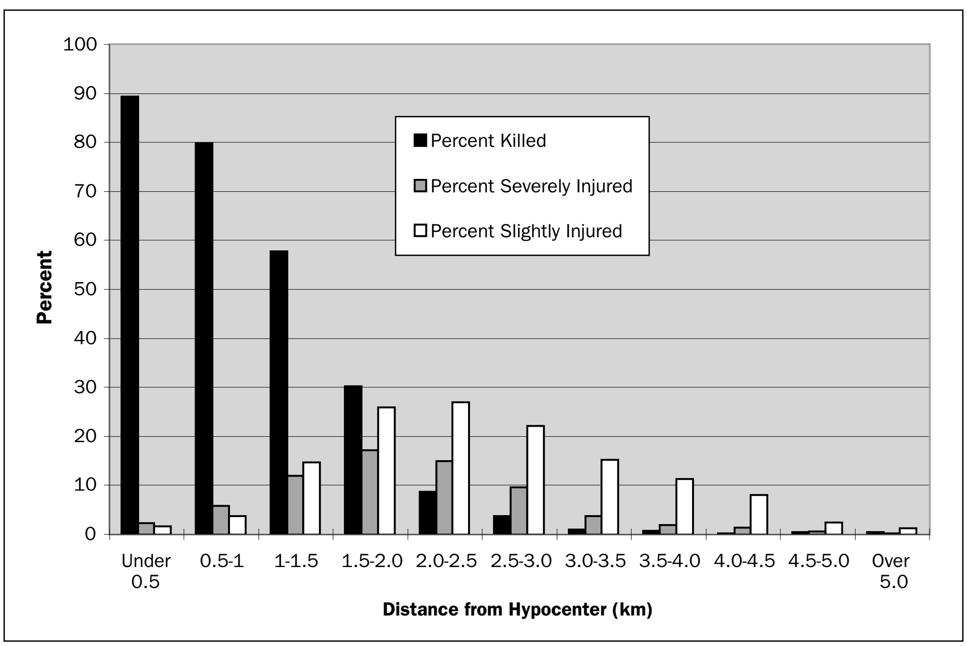
ten times higher. Clearly, to accurately calculate nuclear conflict, nuclear weapon design details become important variables.

Estimating Deaths and Injuries from Nuclear Explosions

In 1945, two nuclear weapons—primitive by today's standards—killed over 210,000 people in the Japanese cities of Hiroshima and Nagasaki.[26] The uranium gun-type nuclear weapon used in the Hiroshima attack had an estimated yield of 15 kt,[27] and was detonated at 580 meters above the surface.[28] The deaths and injuries are plotted in Figure 3.6 for concentric 500-meter zones around ground zero. In the innermost zone (out to one-half a kilometer), close to 90 percent of the people were killed. The incidences of severe injury peaked from 1.5 to 2.0 kilometers from ground zero, with incidences of slight injury from 2.0 to 2.5 kilometers. In what follows, we focus on the details of the Hiroshima bombing to help understand the effects of nuclear explosives.

Three weapons effects of the Hiroshima nuclear detonation killed and injured people: blast, thermal radiation, and initial radiation. Because the bomb was detonated in the air at a high height of burst, almost no local fallout occurred. Many of the fatalities were immediate; additional deaths occurred days, weeks, or even years later. The cause of death for the victims varied depending upon whether they were outdoors or inside. Injuries to those people outdoors from thermal burns and initial radiation extended further from ground zero than injuries caused by blast. But for those inside wooden houses, injuries from blast occurred further from ground zero than for thermal burns or initial radiation. In comparison, people inside concrete structures were significantly shielded from all three effects. At the time of the bombing, 8:15 a.m., the air was clear with visibility of up to 20 kilometers, and many people were outdoors in light clothing.

FIGURE 3.6
Hiroshima Casualties
This graph shows the percentages of persons killed, severely injured, or slightly injured as a function of distance from the Hiroshima hypocenter (i.e., ground zero).[29]



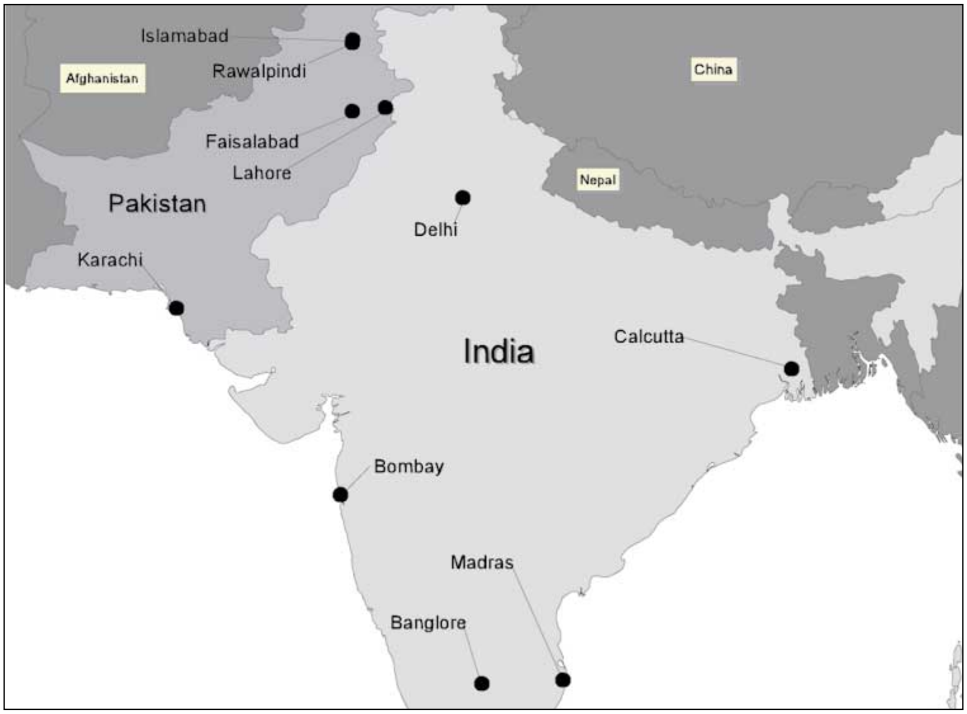


FIGURE 3.7
Ten Indian and Pakistani Cities for Which Hiroshima-Like Casualties Were Calculated

As a first step towards estimating the consequences of nuclear conflict today, the Hiroshima death and injury rates can be superimposed on the population patterns of major urban areas. The same conditions will not apply, such as the number and types of structures and houses, the weather, and the topography, but Hiroshima can provide a point of reference. To illustrate, we have superimposed the Hiroshima rates on the ten major Indian and Pakistani cities mapped in Figure 3.7. Due to much higher population densities, the casualties in the ten South Asian cities are two- to three-times higher than Hiroshima (see Table 3.5).

Clearly, higher-yield weapons can cause many more casualties than the bomb at Hiroshima. To calculate these casualties during the Cold War, the death and injury rates observed at Hiroshima were extrapolated to death and injury rates caused by weapons of other explosive yields. Typically this has been done with emphasis on peak blast overpressure, as seen in an Office of Technology Assessment report, *The Effects of Nuclear War.* Figure 3.8, based on data in that report, shows the percentages of the affected population killed or injured as a function of peak blast overpressure. While the historical record at Hiroshima showed that the distribution of all types of injuries could be roughly correlated with blast effects, this may not be a reasonable assumption for weapons of very different yields. This is because blast effects scale differently with yield compared to other nuclear weapons effects.

For example, in the innermost zone at Hiroshima, less than one-half kilometer from ground zero, 89 percent of the people were killed. From that 15-kiloton bomb at 0.5 kilometers from ground zero the peak blast overpressure was 15.8 pounds per square inch (psi) and the thermal flux was 67.1 cal/cm^2. For a 300-kiloton weapon, detonated at the equivalent altitude of 1,575 meters, an overpressure of 15.8 psi

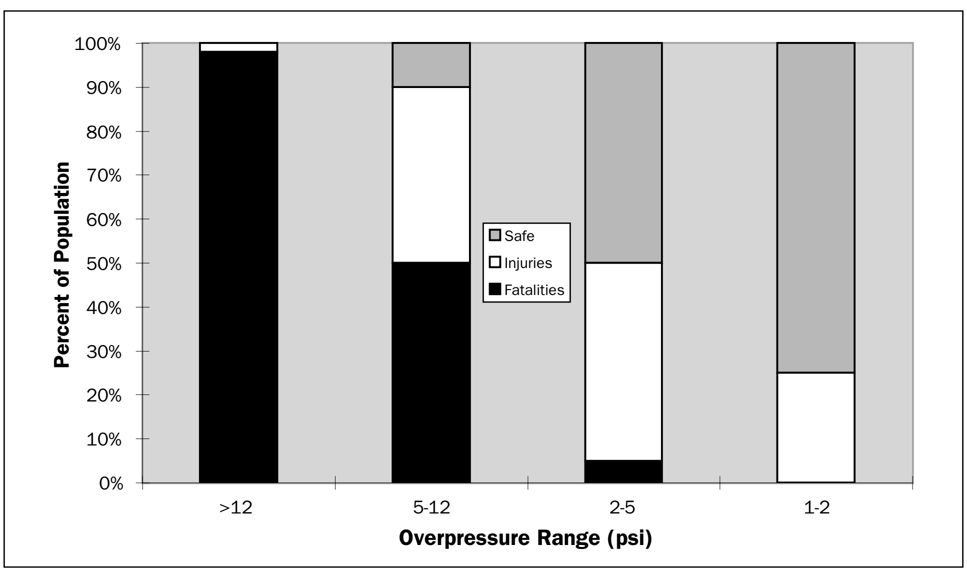
TABLE 3.5
Casualty Calculations for Ten Indian and Pakistani Cities
These calculations use the historical record of Hiroshima casualties as a function of distance from ground zero. Population densities are from the Oak Ridge National Laboratory's "LandScan" data (see below). Ground zeroes were chosen to lie approximately at the centers of these cities.

City Name	Total Population within 5 kilometers of Ground Zero (thousands)	Killed (thousands)	Severely Injured (thousands)	Slightly Injured (thousands)
		India		
Bangalore	3,078	315	175	411
Bombay	3,143	478	229	477
Calcutta	3,520	357	198	466
Madras	3,253	364	196	449
New Delhi	1,639	177	94	218
		Pakistan		
Faisalabad	2,376	336	174	374
Islamabad	799	154	67	130
Karachi	1,962	240	127	283
Lahore	2,682	258	150	354
Rawalpindi	1,590	184	97	221

extends three-times further out to 1.4 kilometers. But at this distance from ground zero, the thermal flux from the 300-kiloton explosion is 166 cal/cm^2. As general rule, the thermal flux increases at a given distance more rapidly than the peak blast overpressure as the explosive yield increases. Therefore the deaths and injuries from a high-yield nuclear explosion are probably underestimated in Figure 3.8. The thermal flux accompanying the blast would cause retinal burns, skin burns, and fires.

MIT physicist, Theodore Postol, calculated that "superfires," produced by much higher-yield weapons than those detonated at Nagasaki or Hiroshima, would create

FIGURE 3.8
Pecentages of the Population Killed, Injured, and Safe
As a function of peak blast overpressure. Source: The 1979 OTA report *The Effects of Nuclear War.*



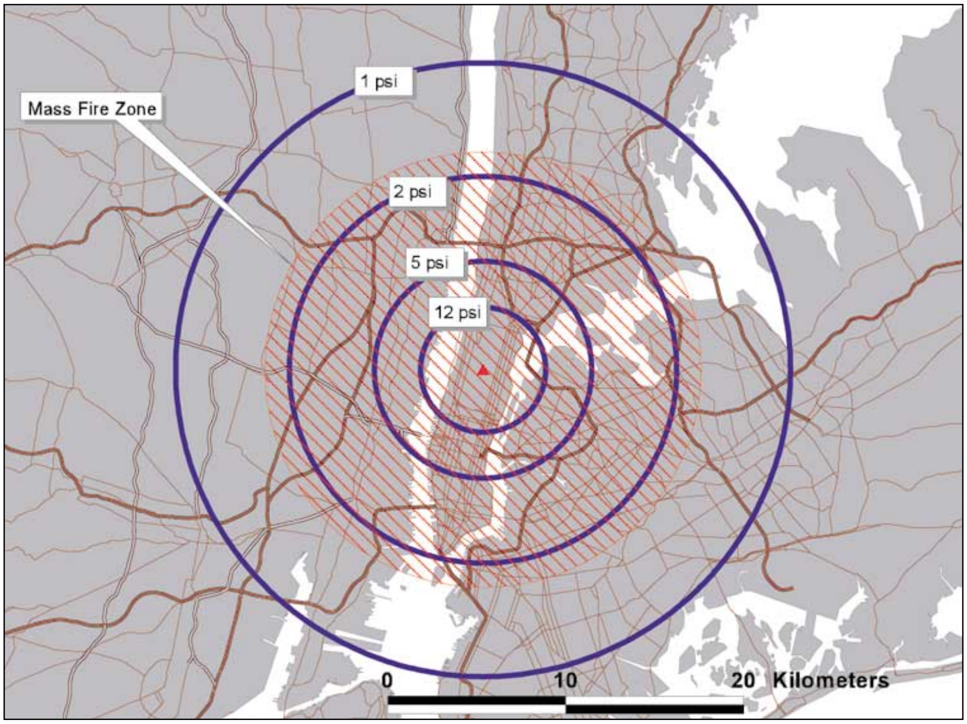


FIGURE 3.9
A One-Megaton Air Burst over New York City
At a height of burst of 2000 meters. Shown in red crosshatch is the zone of "superfires" predicted by Postol's model. The blue rings delineate the casualty zones from the OTA model based on blast effects alone.

high temperatures, noxious smoke fumes and gases, and hurricane-force winds. These superfires would cause mortality to approach 100 percent in urban areas. Postal estimated that the minimum thermal flux required to cause such mass fires was 10 cal/cm^2.[30] The assumption of 100 percent mortality for thermal fluxes greater than 10 cal/cm^2 produces a significant increase in the number of calculated fatalities over the blast model. For example, Figure 3.9 shows a 1 Mt weapon detonated over Central Park in New York City. We calculated 1.25 million deaths and 2.65 million injuries using the blast model of Figure 3.8, while Postol's firestorm model predicts 4.39 million persons would be killed—three-and-a-half-times as many fatalities.

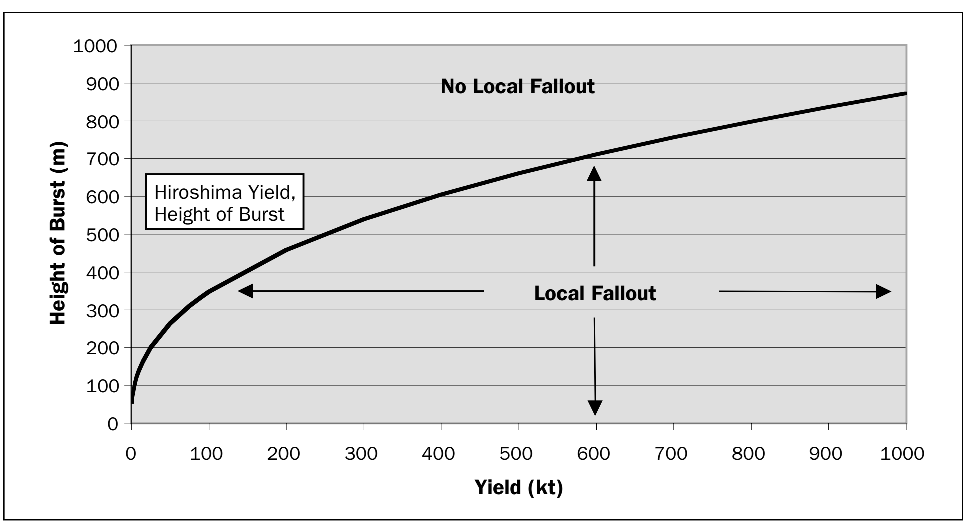


FIGURE 3.10
Threshold Height of Burst for the Occurrence of Local Fallout

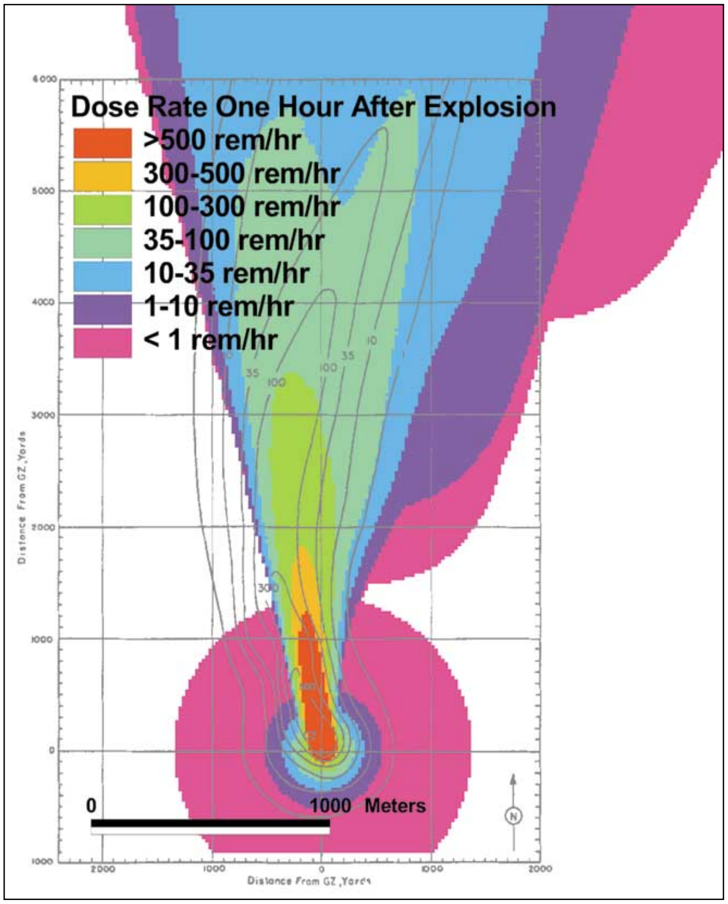


FIGURE 3.11 Fallout Data and Calculations for the U.S. Test "Sugar"

The models we used to calculate deaths and injuries are restricted to the immediate effects of a nuclear detonation. Clearly other effects on the society and the environment will unfold over months, years, or generations. These longer-term effects are beyond the scope of this study, but should be kept in mind. Two key studies focus on these effects: *Life After Nuclear War*[31] by Arthur M. Katz, and a Lawrence Livermore National Laboratory report, "Internal Dose Following A Large-Scale Nuclear War," which examines the long-term impact of fallout on the food supply.[32]

Calculating Fallout from Nuclear Explosions

The residual nuclear radiation produced in a nuclear explosion is defined as the radiation emitted more than one minute after the detonation. Two sources generate residual radiation: neutron activation of the local environment and fallout. Fallout is further divided into early (also called local) fallout and delayed fallout. Early fallout reaches the ground within a day after the explosion, producing lethal radioactive doses to living organisms over potentially large areas. The NRDC Nuclear War Simulation Model incorporates U.S. government software to calculate both neutron activation and local fallout.

Throughout the Cold War, several computer programs were developed to calculate the local fallout from nuclear explosions such as DELFIC,[33] SEER3,[34] or WSEG10.[35] We have chosen to use a Lawrence Livermore National Laboratory (LLNL) fallout computer model known as KDFOC3 (K-Division Defense Nuclear Agency Fallout Code, version 3). KDFOC3 was developed to provide predictive capability for "dirty" and "clean" weapons,[36] for militarily significant radiation levels, and for surface, shallow, and deep burials over a range of yields from one ton to 10 Mt.[37] The algorithms in KDFOC3 use both physics models and empirical data from extensive test film footage and records and fallout measurements from tests conducted at the Nevada Test Site.[38]

Whether early fallout occurs after an explosion depends on the height of burst. If the height of burst is high enough that the nuclear fireball does not touch the ground, then the tiny radioactive particles loft into the upper atmosphere, circulate, and descend to earth over a period of weeks, producing delayed fallout. Delayed fallout spreads over a larger area later in time than local fallout, and therefore the radiation is much less concentrated and has decayed substantially from its initial strength and poses less of an immediate health threat than local fallout. If the nuclear fireball touches the ground, soil particles are drawn into it, mix with the radioactive debris, and produce larger-sized particles—ranging from microns to several millimeters in diameter—which quickly descend to the ground as local fallout. The code KDFOC3 specifies a minimum height of burst for the production of local fallout as a function of weapon yield (see Figure 3.10). Note that for the Hiroshima height of burst—580 meters—no early fallout is predicted for yields less than about 300 kilotons.

NRDC received the KDFOC3 source code from LLNL under a beta-testing agreement. We subsequently modified the source code to run it on a personal computer and to incorporate it into the overall simulation model. In order to understand the predictive capability of KDFOC3, we made comparisons between unclassified fallout data and our own calculations. Observed fallout patterns and other relevant data such as the ambient winds have been compiled in a two-volume report by the General Electric Company under contract to the Defense Nuclear Agency.[39] While KDFOC3 is considered one of the best fallout codes, it does have some limitation best seen when compared to fallout measurements.

We ran comparisons for two low-yield U.S. tests conducted at the Nevada Test Site and one high-yield U.S. test conducted in the Pacific. The agreement between the computer calculation and data is good for the 1.2 kiloton test "Sugar" for H+1 dose rates[40] greater than 10 roentgens per hour (see Figure 3.11). The calculation for test "Ess" is in disagreement with the measured fallout contours because the effects of local topography are not included in KDFOC3 and the cloud ran into the nearby Banded Mountain at the Nevada Test Site (see Figure 3.12). In the analysis of nuclear attacks presented later in this report, we calculated fallout patterns for weapon

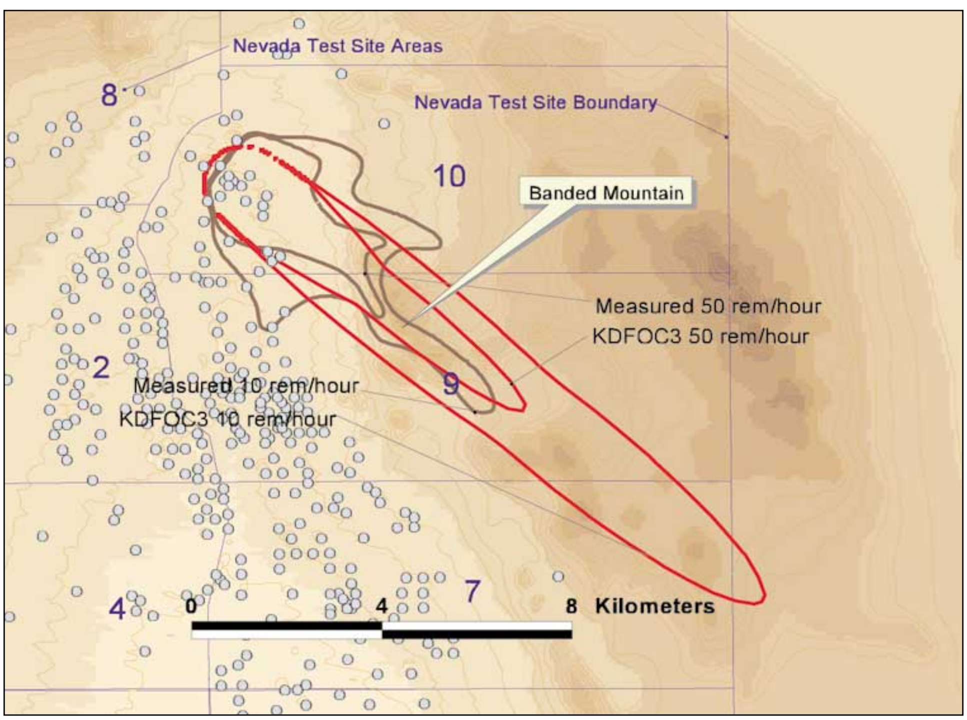
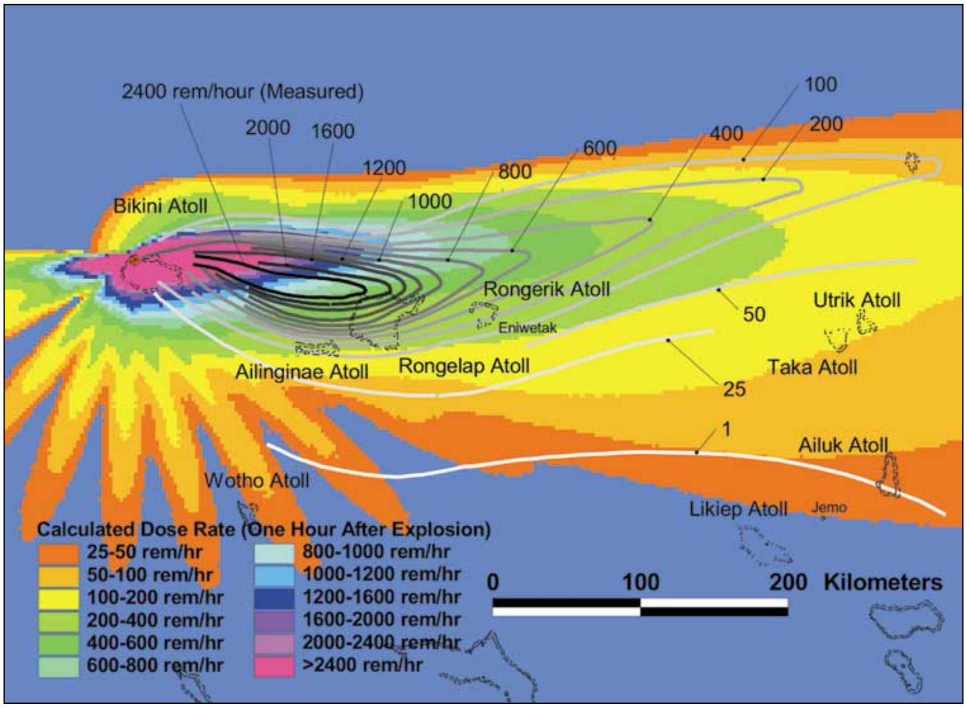


FIGURE 3.12
Fallout Data and Calculations for the U.S. Test "Ess"

FIGURE 3.13
Fallout Data and Calculations for the U.S. Test "Bravo"



yields in the range of hundreds of kilotons. Therefore to illustrate a fallout pattern for a large-yield weapon, we examined data and calculations for "Bravo," which is "one of those used as the basis for fallout prediction for megaton-yield weapons," (see Figure 3.13).[41] For "Bravo," fallout did not begin over much of the contaminated region until many hours after the explosion because of the vast size of the mushroom cloud. Therefore the fallout pattern would be sensitive to any changes in wind speed and direction during that time. KDFOC3 uses a static set of wind parameters that can vary with altitude but are not permitted to vary horizontally.

The initial radiation produced in a nuclear explosion is absorbed by human tissue over a brief time interval. The dose from radioactive fallout, by contrast, will accumulate over days or weeks after a nuclear explosion. While many atomic nuclei are present in the fallout, on average the radiation will decay with time (t) as $t^{-1.2}$. Two days after fallout begins, the dose rate will have fallen to one percent of its original value. During that time, people may seek shielding from the radiation, for example above ground in houses or below ground in basements or fallout shelters. The degree of shielding from the radioactive fallout is quantified in KDFOC3 by a sheltering factor, a number greater than one that is divided into the dose rate. In the calculations performed in Chapters Four and Five, we integrate the fallout dose to humans over the first 48 hours with respect to four sheltering factors: 1 (no sheltering); 4 (above-ground, residential structures); 7 (above-ground, multi-story structures) and 40 (basement environments). In terms of health effects, we assume that a dose of 4.5 Sieverts (Si) will cause death 50 percent of the time, and we use a standard probability distribution for death and severe radiation sickness for other values of the 48-hour integrated dose.

The U.S. Physical Vulnerability System

In Chapter Four, we calculate not only the human casualties and radioactive contamination from nuclear attacks on Russia, but also the probability of damaging or destroying components of Russia's nuclear arsenal. In order to calculate the damage probabilities, we employ the U.S Physical Vulnerability (PV) methodology, a mathematical approach to calculating the probability of achieving a specific level of damage based on the target's ability to withstand the blast effects of a nuclear explosion. In the PV methodology a four-character vulnerability number (VN) is assigned to each target. The vulnerability number, the yield of the nuclear weapon, the distance between the aimpoint and the target, and the CEP provide input data for a set of equations that predict the probability of achieving the specified level of damage.

NRDC obtained an unclassified version of the1989 NATO Target Data Inventory (NTDI) Handbook through the Freedom of Information Act. The 900-page volume identifies 124 categories of Soviet and Warsaw Pact targets for conventional and nuclear weapons. Vulnerability numbers and corresponding levels of damage are given for these target categories and objects associated with them. For example, the document assigns a vulnerability number/damage level assignment of 12P0 for a "Bison (M-4) Long-range Bomber, Nose-on orientation." This rating constitutes a level of damage specified as "Moderate damage to aircraft which requires extensive field level repair consisting of structural failure of control surfaces, fuselage components, and other than main landing gear such as nose, outriggers, or tail."

TABLE 3.6
U.S. DOD Vulnerability Assessments for Nuclear Weapons Blast Effects

Source: *NATO Target Data Inventory Handbook*, 1989.

Object	Damage Level	VN
Single-story, light-steel-framed or reinforced-concrete-framed buildings	Severe structural damage	13Q7
Steel surface storage tanks	Rupture, resulting in loss of contents	21Q9
Exposed aboveground generator set—gas turbine or diesel (2–20 GW)	Overturning and/or severe damage to fuel systems, cooling systems, instrumentation, and power trains.	17Q6
Concrete/Masonry arched dam, 30 m or over	Breach	39P0
Locomotives	Forcefully derailed or overturned.	21Q5
National nuclear-weapon storage bunker	Severe Damage	46P8
Parabolic, solid dish antenna	Moderate Damage	10Q6
SS-11/19 (Silo type III-G MOD)	Severe Damage	55L8
Bison (M-4) Long-range Bomber, Nose-on orientation	Moderate damage to aircraft which requires extensive field level repair consisting of structural failure of control surfaces, fuselage components, and other than main landing gear such as nose, outriggers, or tail.	12P0

The first two digits of the vulnerability number relate to the peak overpressure or peak dynamic pressure corresponding to a 50 percent probability of achieving the designated level of damage. The third character (a letter) of the VN specifies whether the damage probability should be calculated using peak overpressure or peak dynamic pressure, and how rapidly the damage probability falls off with distance. The last character, known as the "K-factor," accounts for the increase in the duration of the blast wave with increasing yield. For targets assigned a non-zero K-factor, a higher-yield weapon will have a greater probability of destroying a target at a given pressure than a lower-yield weapon because the blast wave from the higher-yield weapon acts over a longer time. For further explanation of the PV methodology see Appendix D.

We have incorporated the PV system into the NRDC Nuclear War Simulation Model. We have amassed well over a thousand VN assignments—VN numbers and an associated level of damage—for a wide range of target types (see Table 3.6).[42]

METEOROLOGICAL DATA

Wind speed and direction as a function of altitude has a significant impact on fallout patterns. In order to calculate fallout patterns, we used the "Global Gridded Upper Air Statistics" (GGUAS) produced by the National Climactic Data Center.[43] For cells measuring 2.5 degrees latitude by 2.5 degrees longitude covering the globe, wind rose data are provided at 15 elevations (more specifically, pressure levels) by month, typically to about 30 kilometers above the earth's surface. The spatial resolution of a 2.5-degree cell is about 250 kilometers near the equator. These wind roses are not discrete measurements or even averages, but instead are the output of a global circulation model fitted to many measurements made in each latitude-longitude cell. For each NRDC fallout calculation, the most probable wind direction and speed as a function of altitude for the user-selected month is read as input from the GGUAS cell containing the target.

RUSSIAN DEMOGRAPHIC DATA

To make our nuclear war simulation model as accurate as possible, NRDC drew on the most current Russian population information available. We obtained population data for Russia from the 1989 Soviet Census published in electronic form by East View, and the LandScan world population dataset from Oak Ridge National Laboratory.

The Last Soviet Census

The last census of the Soviet Union was the All-Union Population Census of 1989, published in 1992, and released in electronic form by East View Publications in 1995. The census gave the population figures for four political-administrative levels. The largest were Republics of Ukraine (18 percent of the Soviet population), Uzbekistan (6.9 percent), Kazakhstan (5.8 percent) and Belarus (3.5 percent). All of the republics are now independent countries. The next level includes the *oblasts*, *krays*, and Autonomous Republics. These are further broken down into gorsovets (Soviet cities), urban *rayons*, and *rayons.* A *rayon* is somewhat analogous to a U.S. county. Fourth there is the population in smaller cities, villages, or other named settlements. Generally the rural population is assigned to *rayons.*

In 1989 Russia's total population was 147,021,869, just over half of the total Soviet population of 285,742,511. Nearly three-quarters of the Russian population was classified as "urban." The census listed a total of 3,230 urban settlements, with 1,037 classified as "cities" and 2,193 classified as "urban-type settlements." The cities had a population of 94,840,355, or 87.8 percent of the urban population. Early in this NRDC project, we geo-referenced most of the urban settlements and many of the rural settlements using latitude/longitude coordinates from ESRI's Digital Chart of the World (see below) or the NIMA Geonet Names Server. Figure 3.14 is a map of cities and other settlement types for European Russia, west of the Ural Mountains. Figure 3.15 is a map of the population centers for Siberia and parts of the Russian Far East, many of which are located along railroads.[44] *Rayons* and *gorsovets* vary in size from 1,400 square kilometers in the central economic region around Moscow, to *oblast* areas of up to one-half million square kilometers in the sparsely populated regions west of the Ural Mountains (see Figure 3.16).

To calculate casualties from nuclear attacks in or near large urban areas, we preferred to show population spread throughout the area instead of assigning an entire population to a single point at the center of a city (see Figures 3.14 and 3.15). Population densities in urban areas can be estimated using ESRI's Digital Chart of the World data. A second method for handling urban areas, used by some U.S. Department of Defense contractors, is to devise a general formula for population density. For example, *The Feasibility of Population Targeting* report (discussed in

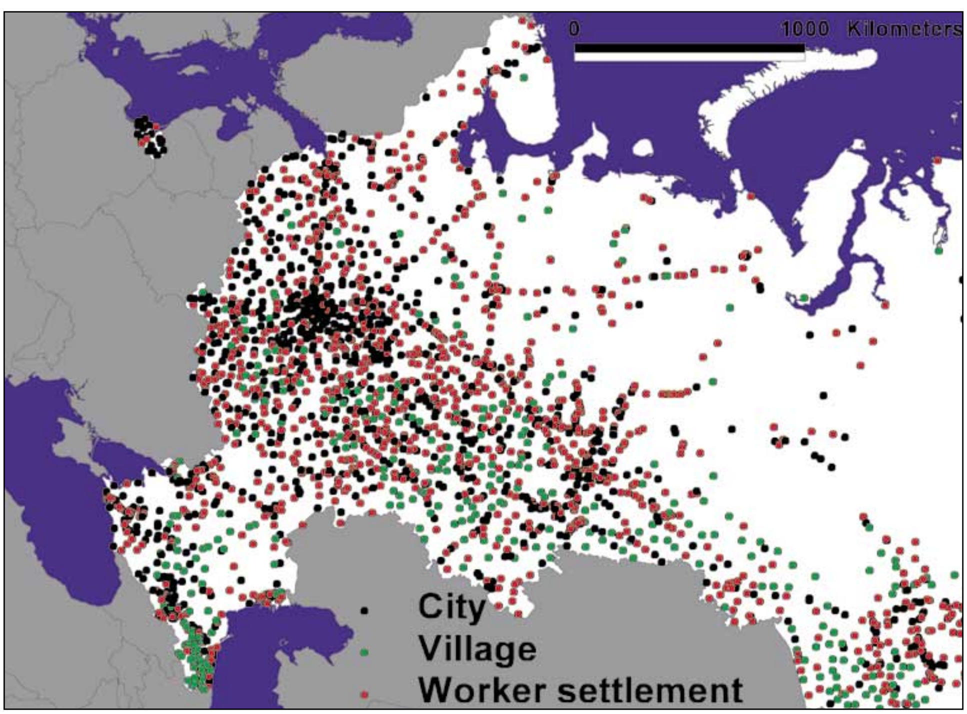
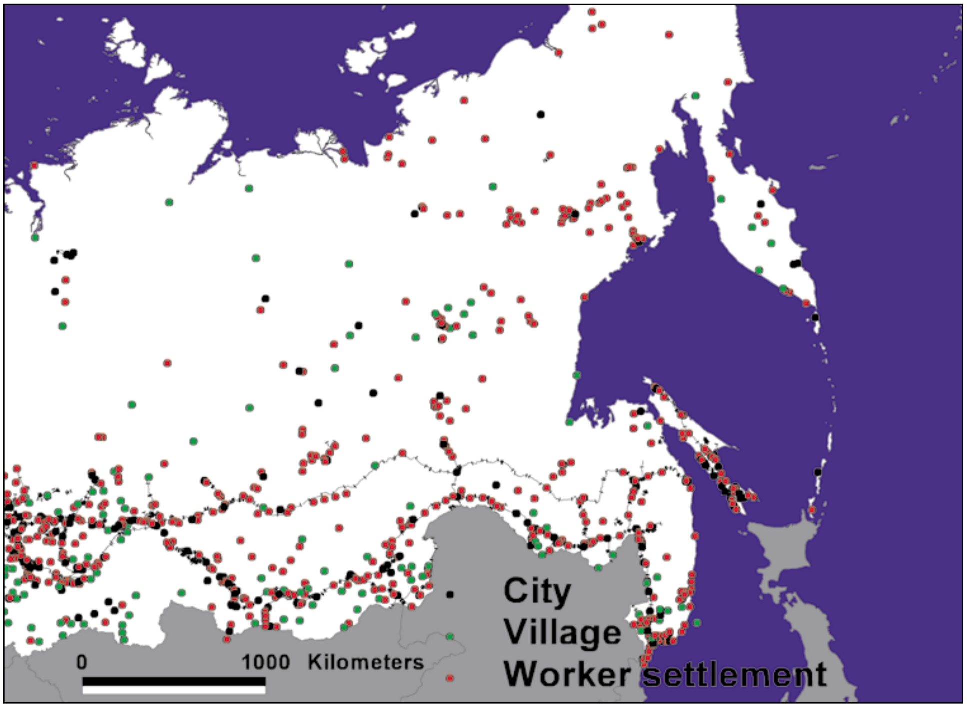


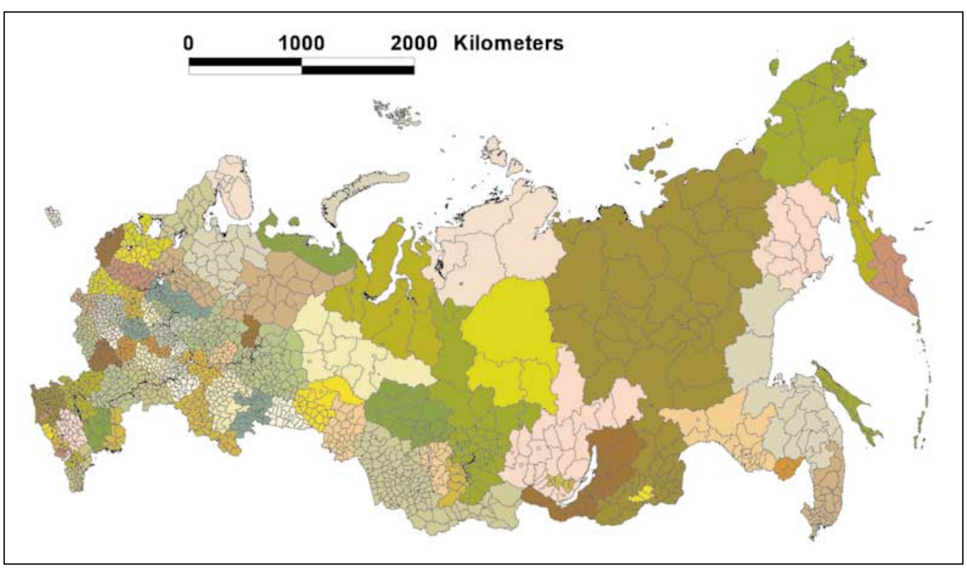
FIGURE 3.14
Geo-referenced Population Centers, European Russia
Source: 1989 Soviet Census.

FIGURE 3.15
Geo-referenced Population Centers, Siberia and Far East
Note the distribution of population centers along railroads (railroad data from ESRI's Digital Chart of the World). Source: 1989 Soviet Census.



Chapter Five), assumes population in urban areas is concentrated in the center and decreases towards the outskirts of the city in a specific manner.[45] Here the radius of a circle enclosing 95 percent of a city's population is related to the total population by the formula: radius (P-95) = $0.5125 \times \ln(1.3 + 0.2\ P)$, where the P-95 radius is in nautical miles and the population, P, is in thousands.[46] The census data does not account for variations in population densities in rural areas within *rayons.* These limitations can be overcome by using Oak Ridge National Laboratory's LandScan data.

FIGURE 3.16
The 87 Russian Political-Administrative Units
These units are shown as the following types: *kray, oblast,* republic, autonomous district, autonomous oblast, and city of federal significance—Moscow and St. Petersburg are shown as colored polygons. The 2,305 political-administrative sub-units (*rayon,* ethnic administrative *rayon,* and *gorsovet*) are shown in black outline. Alexander Perepechko and Dmitri Sharkov at the University of Washington compiled these spatial data.



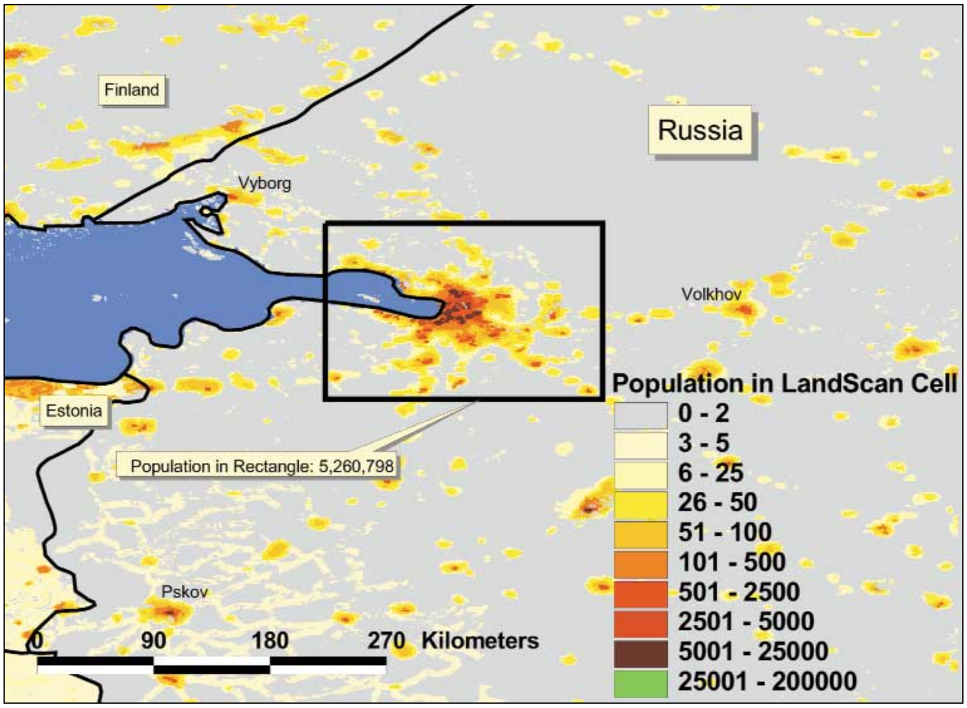


FIGURE 3.17
U.S. Government-Produced LandScan Population Distribution for the St. Petersburg Vicinity
Using the LandScan dataset, it is possible to draw an arbitrary shape (like the rectangle around St. Petersburg) and determine the enclosed population (5,175,973). This capability is necessary to sum populations subjected to nuclear effects, e.g. overpressure or fallout. USSTRATCOM uses this dataset for this purpose.

LandScan

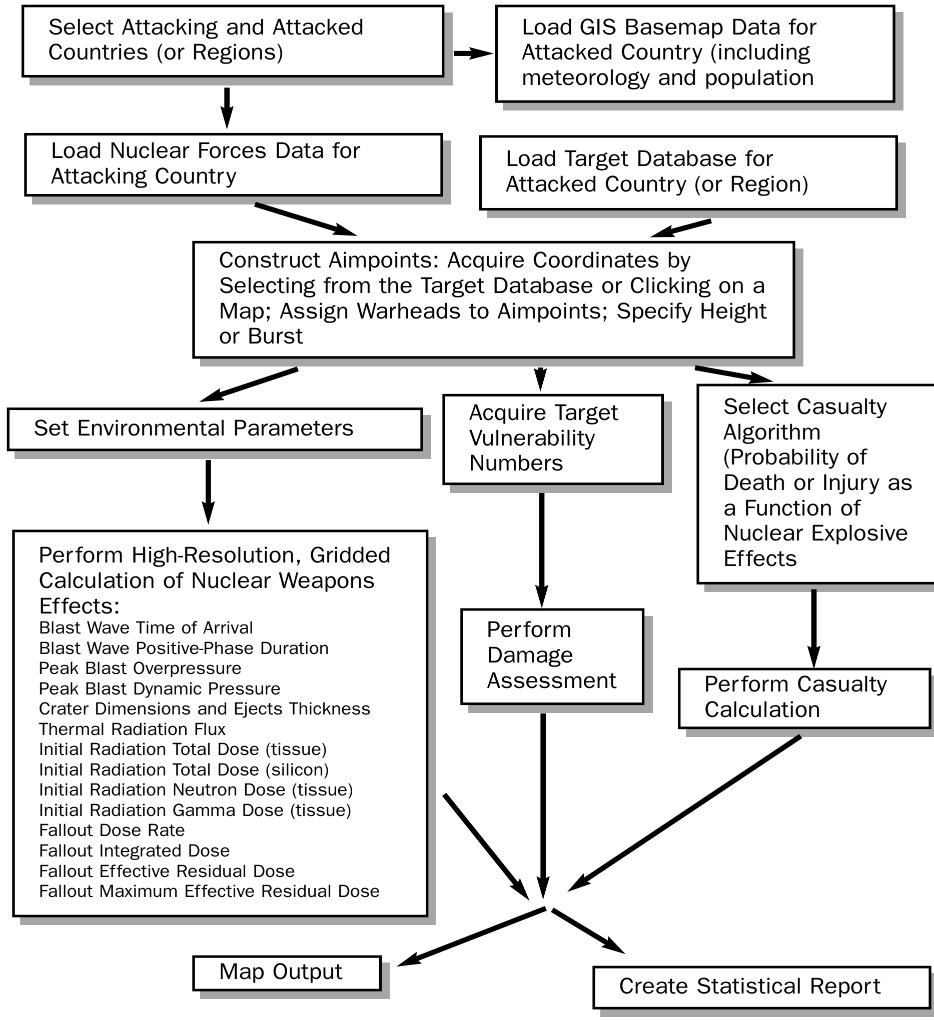
While the Russian census helped us begin compiling our population information, it did not provide clear information on population density. Fortunately, NRDC later acquired a set of unclassified view-graphs of a USSTRATCOM presentation that showcased their advanced capabilities to simulate nuclear conflicts. It became clear that the nuclear war planners had grappled with the same problem and created some interesting solutions. For instance, when U.S. planners worked on the Red Integrated Strategic Offensive Plan—the hypothetical Russian nuclear war plan envisioned by the United States—they used world census data collected and analyzed by the U.S. Census Bureau. These population distributions had been comprised of P-95 circles, as described above, and rural cells.

More recently, USSTRATCOM asked the Oak Ridge National Laboratory to generate a superior world population distribution for use in SIOP planning called "LandScan."[47] For LandScan, world census data is allocated to 30 arc-second cells (cells with areas less than 1 km^2) based on criteria such as nighttime lights as observed from satellites, proximity to roads, terrain slope, etc. We integrated the LandScan data into our simulation model. This enables us to calculate casualties based upon the same demographic data that is used by USSTRATCOM's war planners. Figure 3.17 shows the LandScan population distribution for St. Petersburg and the surrounding area.

PUTTING IT ALL TOGETHER: THE NRDC SOFTWARE AND DATABASE SUITE

The NRDC software and database suite for simulating nuclear conflict is built on the Geographic Information System (GIS) software package ArcView, a product of the

FIGURE 3.18
The NRDC Nuclear War Software and Database
A flow-chart of the basic functions of the NRDC nuclear conflict software and database suite.



ESRI Corporation. In the course of this project, NRDC and its consultants have written over 6,000 lines of computer code in both the Avenue and FORTRAN programming languages to achieve the current set of analytical capabilities. The data and formulas discussed above—those related to attacking nuclear forces, attacked nuclear targets, nuclear weapons effects, weather and demographics, as well as a host of other data relating to political boundaries and geography—are loaded into the GIS application or accessed during calculations as separate data and executable files. The data set of potential targets, in the form of Microsoft Access database files, can be queried directly by the software through an object database connection (ODBC). Effects of nuclear explosions—blast, thermal, initial radiation, and fallout—are calculated, displayed, and further analyzed to derive information such as damage assessments against specific targets and the number of casualties. Figure 3.18 is a flow-chart of the basic functions of the NRDC software and database suite.

CHAPTER FOUR

Attacking Russia's Nuclear Forces

In this chapter, we put the analytical tools of our model to work describing a major U.S. attack on Russia's nuclear forces. The attack scenarios use land-based and sea-based strategic missiles to deliver between 1,124 and 1,289 warheads with an explosive yield of between 294.9 and 320.6 megatons. The ranges represent low and high levels of targeting against Russian strategic naval and aviation sites. This is a type of attack that has traditionally been an option in the U.S. SIOP. At times it was designated MAO-1, for Major Attack Option-1. This chapter presents NRDC's approximation of that kind of attack, which we will call Major Attack Option-Nuclear Forces (MAO-NF).

In our analysis, we cover the eight categories that currently make up the infrastructure of Russia's nuclear forces—the likely targets in an attack of this kind. These categories include: silo-based, road-based, and rail-based ICBMs, SSBN and long-range bomber bases, nuclear warhead storage sites, the nuclear weapons design and production complex, and command, control, and communication facilities. This kind of attack is termed a "counterforce" attack because the targets are military rather than civilian and because heavily populated areas are excluded. In this case, the military targets are all nuclear related. Russian/Soviet forces in the recent past were many times their current size. If existing trends continue, they probably will be much smaller in the future. Nevertheless, a detailed examination of a U.S. counterforce attack today can be a benchmark case study to help analyze future arsenals and different-sized attacks.

We divide our discussion of each of the eight Russian target categories into three subsections. The first subsection describes the kinds of targets in each category. The second subsection explains our reasons for selecting the attacking warhead aimpoints, the height of bursts, and the number of warheads per target. We base these selections on detailed analysis of the vulnerability of the targets to nuclear explosions. The third subsection describes the scale of casualties that result from the attack. As we shall see, the numbers of casualties depend upon several parameters that are included in our model. The monthly variation in wind speed and direction, for example, affects fallout patterns. We treat two other important parameters—the degree of population sheltering from fallout and the fission fraction of the total yield of a thermonuclear warhead—as uncertainties in our calculations.

At the end of the chapter, we summarize our results by totaling and assessing what happens in each of the eight categories to both people and targets. Depending upon the time of year, our statistical assessment is that the MAO-NF attack employing 1,289 U.S. warheads causes between 11 and 17 million casualties, including between 8 and 12 million fatalities.

SILO-BASED ICBMS

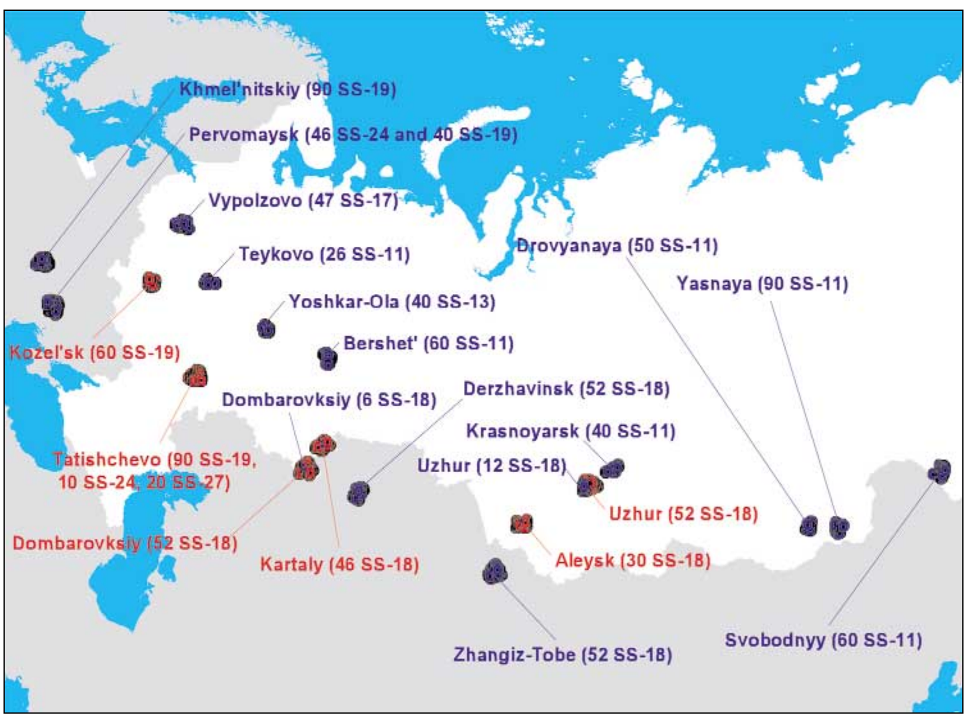
Description of Targets

As of mid-2001, Russia has 360 operational ICBM silos and 52 associated silo launch control centers distributed throughout six missile fields: Kozelsk, Tatishchevo, Uzhur, Dombarovskiy, Kartalay, and Aleysk. These fields are arrayed in a 3,700-kilometer arc from just west of Moscow eastward to Siberia. Many of these silos will be eliminated if START II enters into force. Since the end of the Cold War, the number of silos, missiles, and the nuclear warheads they carry has been reduced greatly, in part a result of the Strategic Arms Reduction Treaty I (START I). This is depicted in Figure 4.1. The current ICBM force consists predominantly of SS-18s and SS-19s, with a modest number of SS-24s and SS-27s.

Warhead Requirements and Aimpoints

To attack a missile silo with a nuclear weapon, a war planner must make some estimate as to how "hard" it is. The degree of "hardness" determines the silos' ability to withstand the effects of a nuclear explosion—and thus protect the underground missile. The vulnerability numbers for former and current Russian silos are listed in Table 4.1. Using these assigned vulnerability data, we calculate the damage radii for severe or moderate damage to each silo type by a 300-kt W87 (U.S. MX/Peacekeeper ICBM)

FIGURE 4.1
Past and Present ICBM Silo Fields
The 360 active (colored red) and 711 dismantled (colored blue) missile silos in Russia and the former Soviet Union. Note several of the fields were in Ukraine and Kazakhstan.



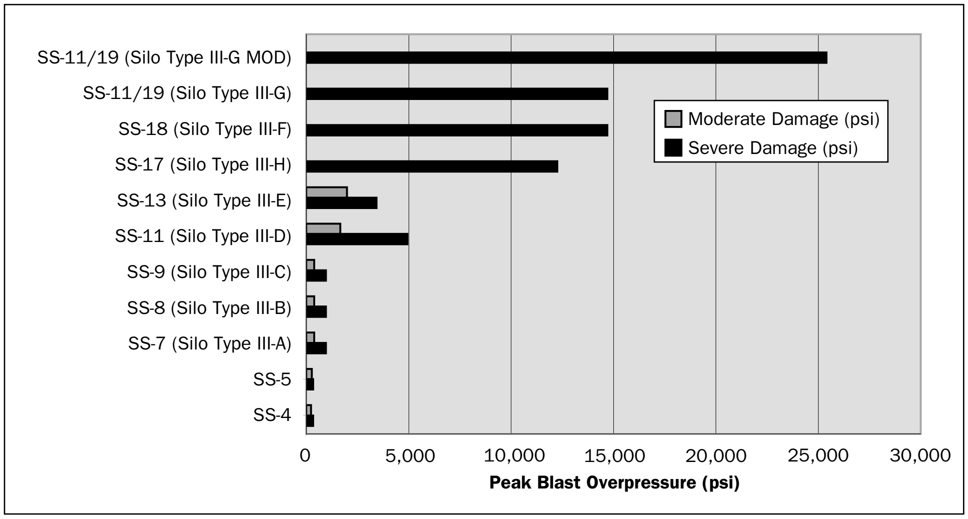


FIGURE 4.2
Peak Blast Overpressure Damage to Soviet-Built Silos
These values of peak blast overpressure are computed to produce a 50 percent probability of severe or moderate damage to the indicated silo types. Note that the correction for the yield-dependent blast wave duration (given by the vulnerability number's K-Factor) is not applied in this figure.

warhead (also given in Table 4.1). These calculations show the progressive hardening of ICBM silos during the Cold War.[1] The severe damage radius for a 300-kt ground burst on the hardest silo type (type III-G MOD) is computed to be 137 meters. This damage radius is slightly larger than the accuracy of the MX/Peacekeeper (estimated to be 91 meters) and the calculated radius of the crater formed by the ground burst (ranging from 57 meters in hard rock to 115 meters in wet soil). Figure 4.2 shows the computed peak blast overpressure necessary to produce a 50 percent probability of achieving severe or moderate damage for various Soviet silos.

TABLE 4.1
Vulnerability Numbers for Soviet-Built Silo Types
N/A indicates "a lesser level of militarily significant damage has not been defined." The computed damage radii for a 300-kt warhead (the yield of the U.S. Peacekeeper warhead) are for surface bursts. Source for the vulnerability numbers: *NATO Target Data Inventory Handbook* (1989).

Missile System	Year Missile System First Deployed	Silo Type	VN[2] for Severe Damage[3]	300-kt Severe Damage Radius (meters)	VN for Moderate Damage[4]	300-kt Moderate Damage Radius (meters)
SS-4	1958	—	31P1	491	29P0	551
SS-5	1961	—	31P1	491	30P0	514
SS-7	1962	III-A	37P6	390	32P2	471
SS-8	1963	III-B	37P6	390	32P2	471
SS-9	1967	III-C	37P6	390	32P2	471
SS-11	1966	III-D	46L8	241	40L6	311
SS-13	1969	III-E	44L7	254	41L6	291
SS-17	1975	III-H	51L7	164	N/A	N/A
SS-18	1974	III-F	52L7	154	N/A	N/A
SS-11/19	1974	III-G	52L8	165	N/A	N/A
SS-11/19	1974	III-G MOD	55L8	137	N/A	N/A

U.S. war planners calculated that blast overpressures of 10,000 to 25,000 psi were required to severely damage the hardest Russian silos. These figures, and even higher ones, have been cited in the open literature.[5] Clearly this assessment of the hardness of Russian silos has a significant impact on the U.S. nuclear war planning process. For example, in an *Air Force* article, the Commander-in-Chief of Strategic Air Command, Gen. Bennie Davis stated: "Anytime you can get superhardening values well above 6,000 psi, you automatically complicate the targeting problem [i.e., for the attacker]."[6] According to General Davis, the complication is partially overcome by assigning "two or more RVs" to achieve the requisite high kill probability. The following figures illustrate General Davis' point: the probability of severely damaging a SS-11 silo (5,000 psi) using one Minuteman III (MM III) W78 warhead is 0.66 (assuming a yield of 335 kt and a CEP of 183 meters), whereas the probability of using one such MM III warhead on a SS-17 silo (12,000 psi) is only 0.39. The probability of severely damaging a SS-17 silo increases to 0.63 if two such MM III warheads are used and to 0.77 if three such MM III warheads are used.

By raising the height of burst above ground level, it is possible to reduce the total amount and extent of lethal fallout.

To achieve maximum kill probabilities against Russian ICBM silos, we assume that U.S. war planners assign accurate warheads with high yields to these targets. The most likely U.S. weapons they would assign would be W87 and W78 ICBM warheads and W88 and W76 SLBM warheads. U.S. nuclear-armed cruise missiles or bombers take too long to reach the silos considering the probable requirement in the SIOP to attack the silos before Russian forces launch the missiles. Table 4.2 shows the single-shot kill probabilities (SSPK—one warhead per silo) and double-shot kill probabilities (DSPK—two warheads per silo) for ground bursts of various U.S. ICBM and SLBM warheads. While ground bursts produce higher kill probabilities, they also cause more extensive fallout.

Achieving significant kill probabilities requires at least one MX warhead, or one W88 warhead, per silo, especially for the SS-11/19 III-G MOD silo type. To generate high probabilities of severe damage requires allocating two such warheads per silo.

TABLE 4.2
Single-Shot and Double-Shot Kill Probabilities for U.S. ICBM and SLBM Warheads Attacking Active Russian Silo Types
For Trident I and II warheads, a range is given for circular error probable (CEP). Single-shot kill probabilities are indicated by SSPK, and double-shot kill probabilities are indicated by DSPK.

Warhead	Yield (kt)	CEP (m)	SSPK (SS-18, Silo Type III-F)	DSPK (SS-18, Silo Type III-F)	SSPK (SS-11/19, Silo Type III-G)	DSPK (SS-11/19, Silo Type III-G)	SSPK (SS-11/19, Silo Type III-G MOD)	DSPK (SS-11/19, Silo Type III-G MOD)
W76 (Trident I)	100	500	0.022	0.044	0.024	0.047	0	0
W76 (Trident I)	100	229	0.103	0.195	0.112	0.211	0	0
W76 (Trident II)	100	183	0.155	0.286	0.169	0.309	0	0
W76 (Trident II)	100	129	0.286	0.490	0.309	0.523	0	0
W62 (MM III)	170	183	0.230	0.407	0.254	0.443	0.183	0.333
W78 (MM-III)	335	183	0.360	0.590	0.403	0.644	0.299	0.509
W88 (Trident II)	475	183	0.442	0.689	0.496	0.746	0.375	0.609
W88 (Trident II)	475	129	0.687	0.902	0.744	0.934	0.608	0.846
W87-0 (MX)	300	91	0.805	0.962	0.848	0.977	0.726	0.925

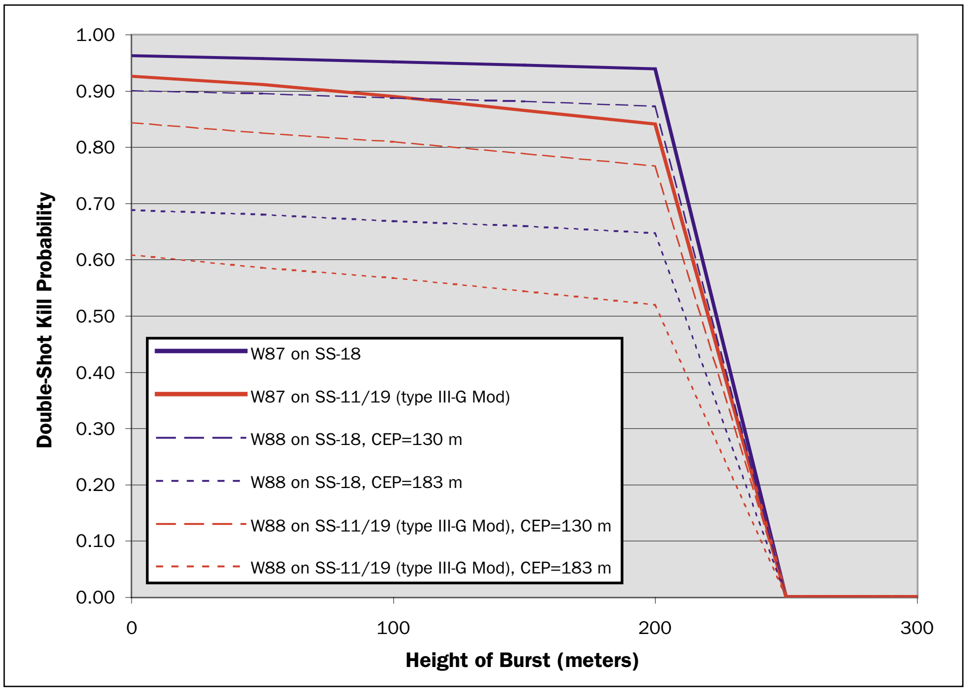


FIGURE 4.3
Double-Shot Kill Probabilities for W87 and W88 Warheads Against Russian SS-18 and SS-11/19 Silo Types
As a function of height of burst.

By raising the height of burst above ground level, it is possible to reduce the total amount and extent of lethal fallout. Figure 4.3 demonstrates that double-shot kill probabilities against Russian silos are roughly constant from a ground burst to a height of burst of about 200 meters, and then quickly fall to zero as the altitude is increased further. The height of burst at which a weapon is detonated will have some error associated with it, called the Probable Error Height of Burst (PEH).[7]

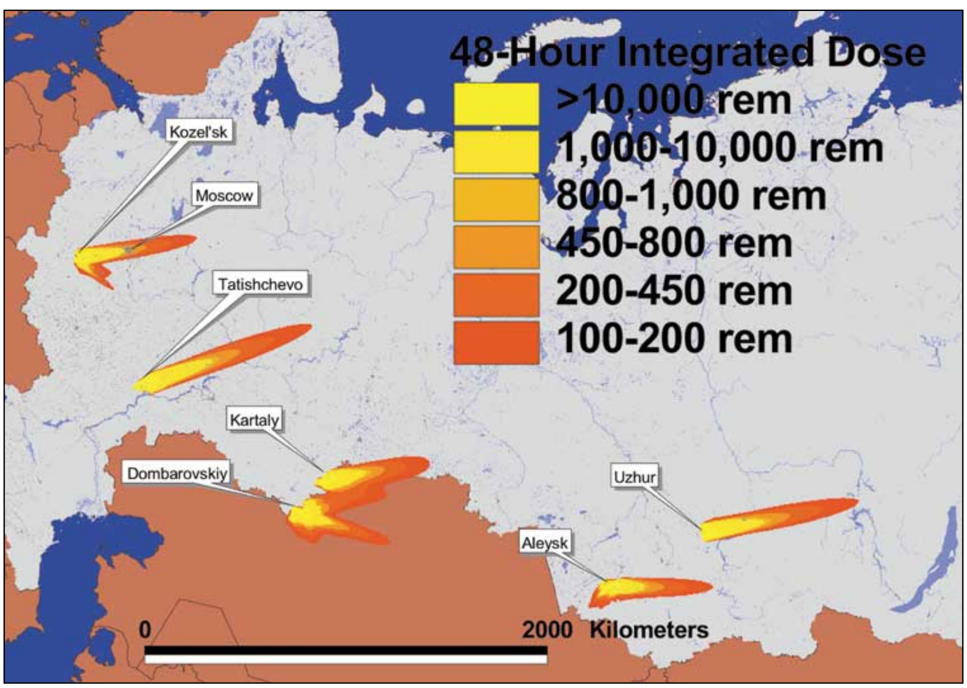
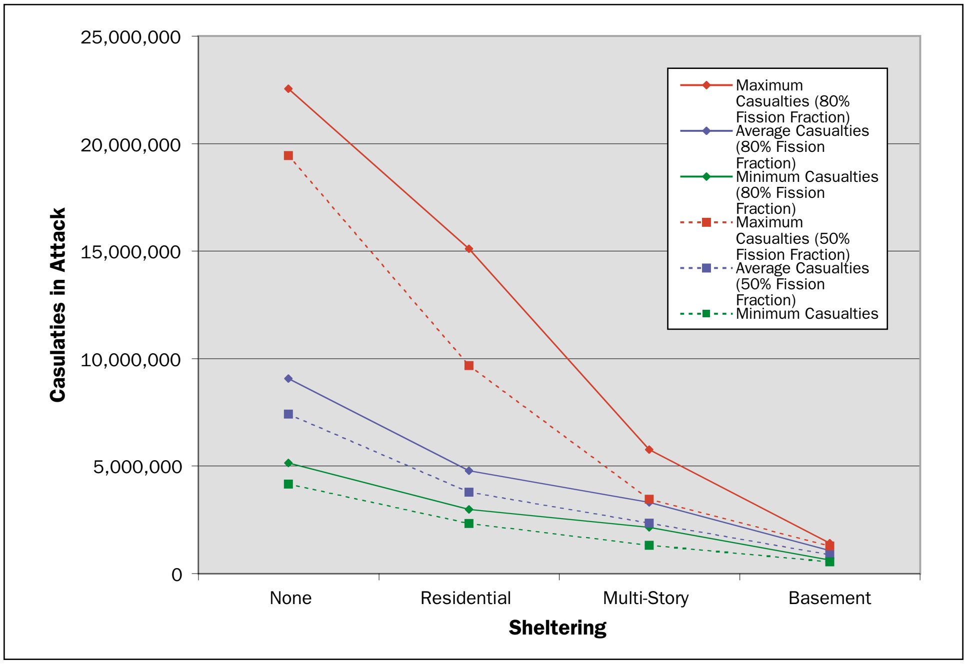


FIGURE 4.4
Fallout Patterns from an Attack on All Active Russian ICBM Silos
This calculation uses wind patterns typical for the month of June and assumes a weapon fission fraction of 50 percent. Radiation dose is integrated over the first two days after the attack for an unsheltered population. For these input parameters, total casualties are calculated to be 19.7 million, 16 million of which are calculated to be fatalities. Over 175,000 square kilometers would be contaminated by fallout to such an extent that unsheltered people would have a 50 percent chance of dying of radiation sickness.

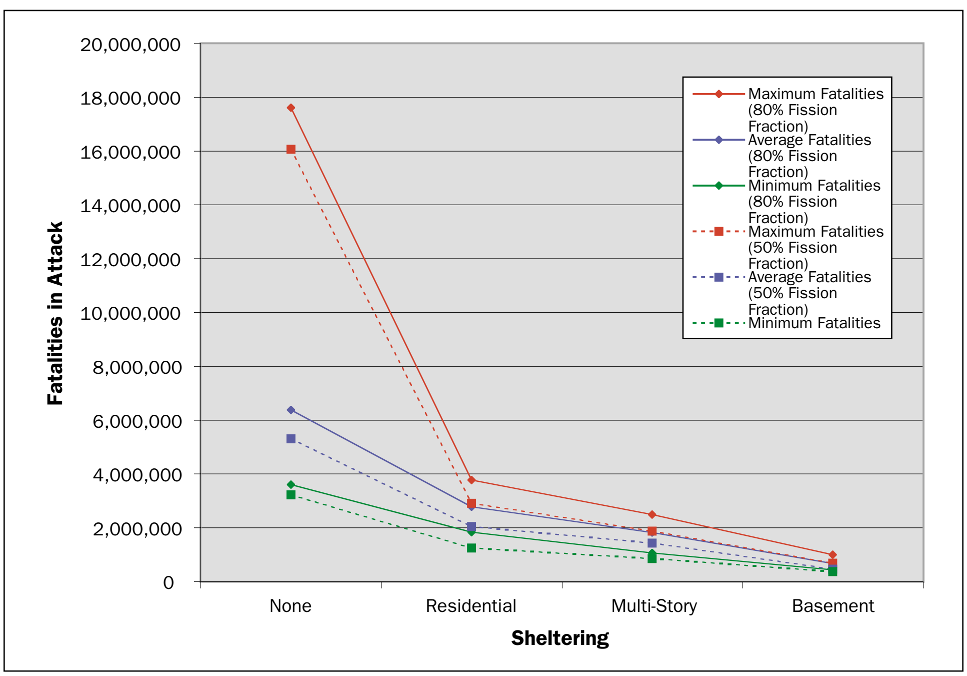
FIGURE 4.5
Summary Casualty Data for an Attack on Russian ICBM Silos
Maximum, mean, and minimum casualty figures are presented as a function of sheltering for assumed warhead fission fractions of 50 and 80 percent.



While we do not know the magnitude of these errors for U.S. nuclear weapons, it is unlikely that the PEH is appreciably less than 200 meters. In this case, ensuring high kill probabilities against silos would necessitate surface bursts.

Based upon the vulnerability analysis and the limited number of high-yield W87 and W88 warheads that are available, we assign two W87 (MX/Peacekeeper) warheads for each of the 150 SS-19 silos (assuming they are of type III-G MOD), two

FIGURE 4.6
Summary Fatality Data for an Attack on Russian ICBM Silos
Maximum, mean, and minimum fatality figures are presented as a function of sheltering for assumed warhead fission fractions of 50 and 80 percent.



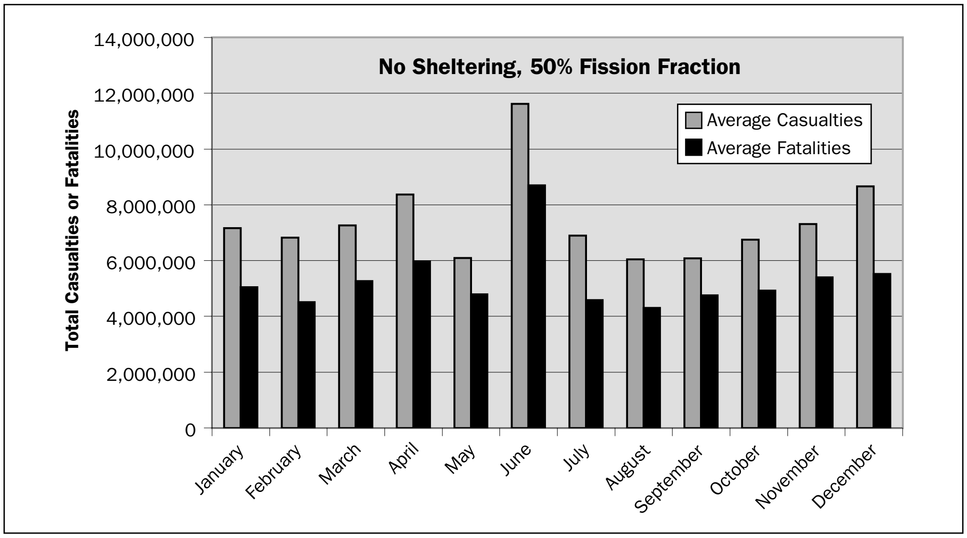


FIGURE 4.7
Monthly Variation of Fallout Casualties for an Attack on Russian ICBM Silos Assuming Weapon Fission Fractions of 50 Percent and No Sheltering
These variations are due to wind speed and direction. Casualties and fatalities have been averaged with respect to the angular resolution of the wind rose data (see Endnote 7).

W87 warheads for each of the ten SS-24 and 20 SS-27 silos (also assuming they are of type III-G MOD), and a mixture of W87 and W88 (Trident II) warheads for the 180 SS-18 silos (assuming they are of type III-F). Our attack on Russian silos uses a total of 500 W87 warheads (all that are available) and 220 W88 warheads (with a cumulative yield of 250,000 kilotons). We select ground bursts for all attacking warheads. Using this warhead allocation for these targets, we calculate that 93 percent of the SS-19, SS-24, and SS-27 silos would be severely damaged (167 out of 180 silos) and 94 percent of the SS-18 silos (169 out of 180 silos) would be severely damaged (see Table 4.2). Only 24 silos would not be severely damaged.

The attack uses 500 W87 warheads—equivalent to all MM III missiles converted to single-warhead missiles carrying the W87 with an improved accuracy of 91 meters. The attack also uses about one-half of the available W88 warheads—slightly more than the maximum number of warheads that could be deployed aboard one Trident

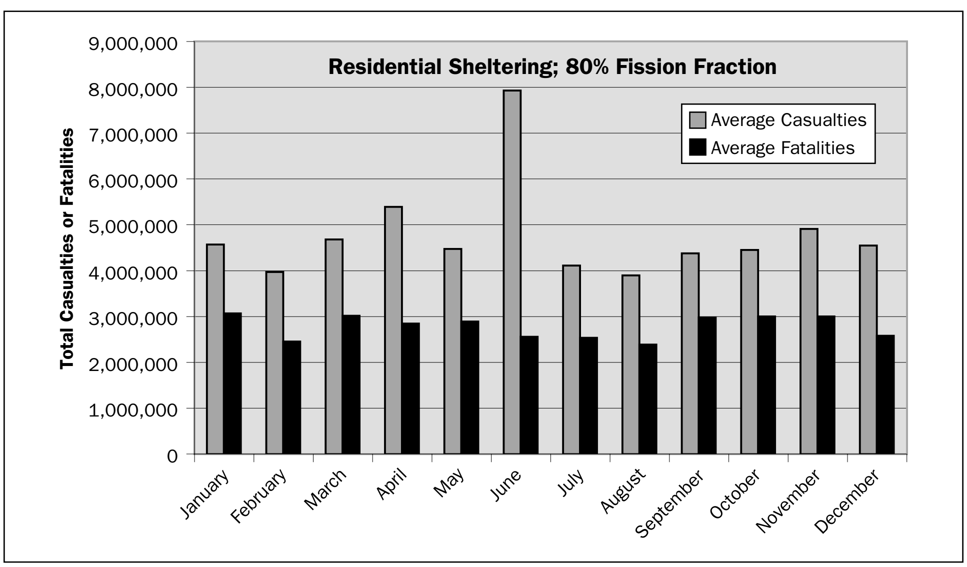
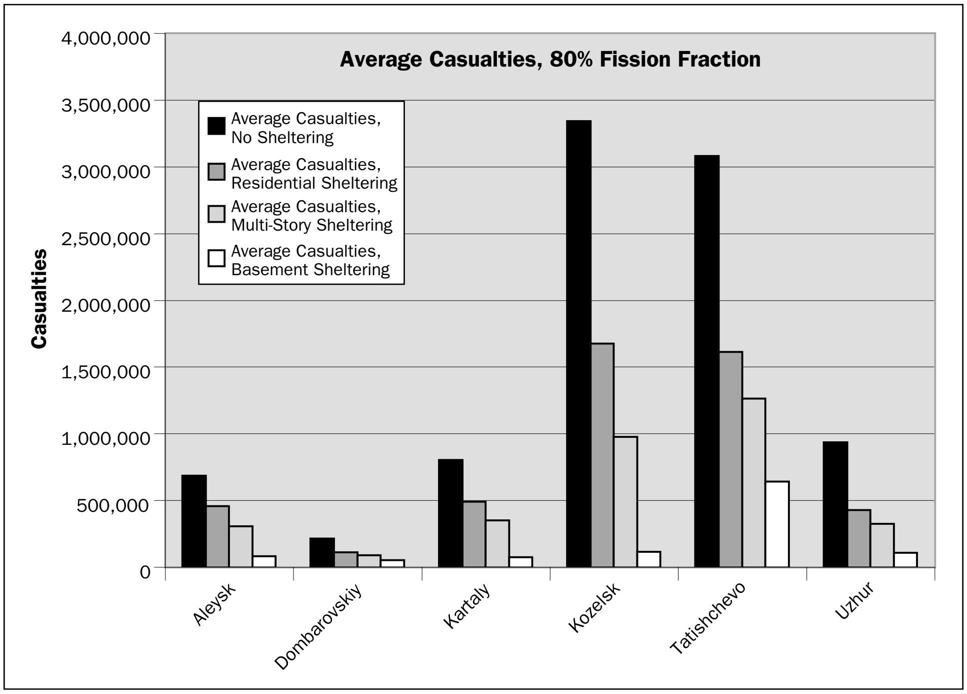


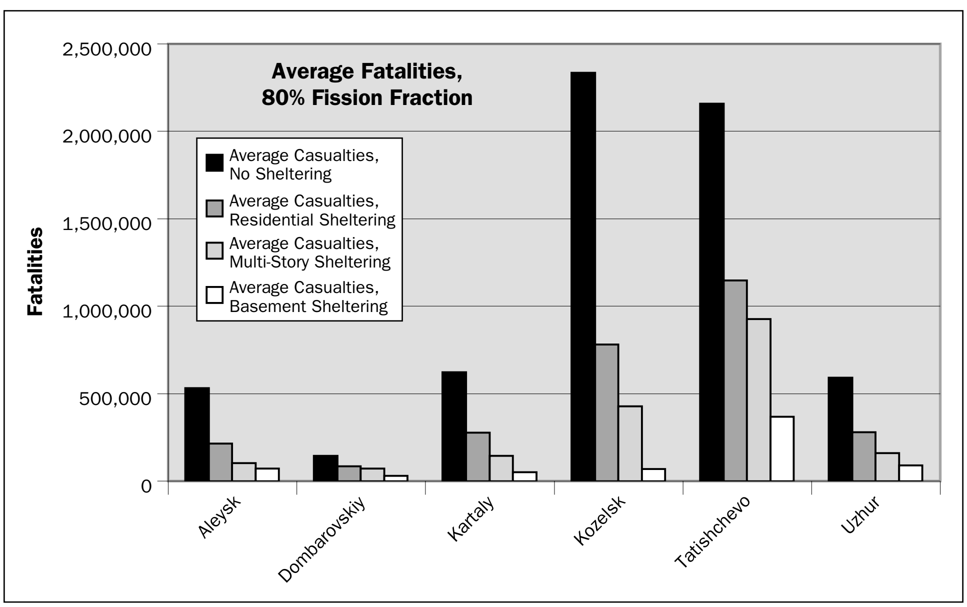
FIGURE 4.8
Monthly Variation of Fallout Casualties for an Attack on Russian ICBM Silos Assuming Weapon Fission Fractions of 80 Percent and Sheltering Typical of Residential Structures
These variations are due to wind speed and direction. Casualties and fatalities have been averaged with respect to the angular resolution of the wind rose data (see Endnote 7).

FIGURE 4.9
Casualties, as a Function of Missile Field and Sheltering
The cumulative yield detonated at each missile field is: Aleysk—28.5 Mt; Dombarovskiy—31.2 Mt; Kartaly—26.6 Mt; Kozelsk—36 Mt; Tatishchevo—72 Mt and Uzhur—49.4 Mt.



SSBN. If an additional 360 W78 warheads (each having a yield of 335 kt and an accuracy of 183 meters) are assigned one to each Russian silo target, the total number of severely damaged silos would only increase by seven. This fact illustrates another complication posed by super-hardened silos: achieving near-100 percent kill against many such targets is only possible by allocating a disproportionately greater number of attacking warheads. At this point of diminished returns, obtained by assigning more attacking warheads to achieve a higher kill probability, an alternative option would be to integrate missile defense capabilities with offensive forces. Finally, it

FIGURE 4.10
Fatalities, as a Function of Missile Field and Sheltering



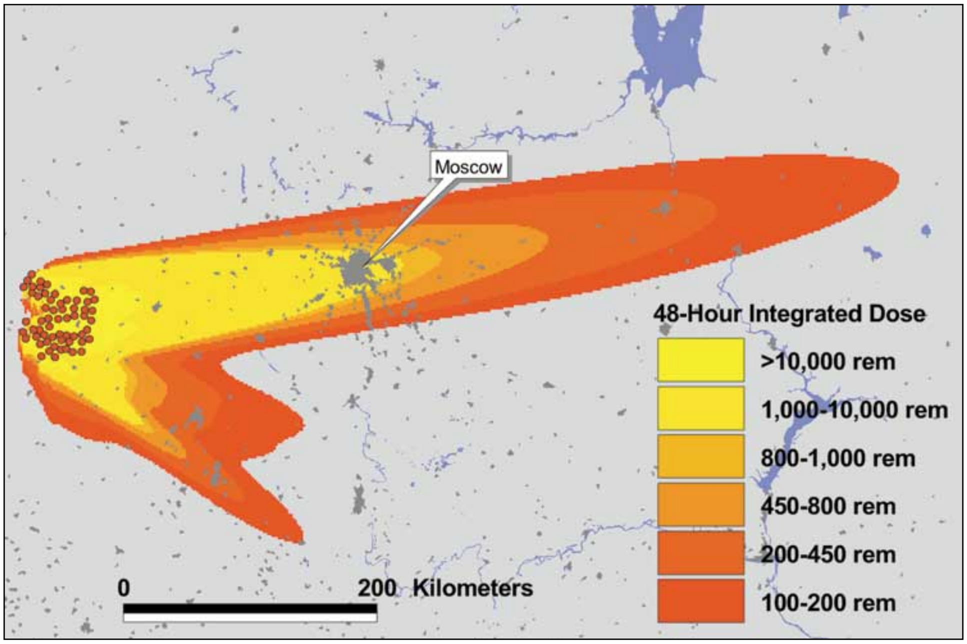


FIGURE 4.11
A Close-up of the Kozelsk Missile Field Fallout Pattern
Calculated for the month of June, with a weapon fission fraction of 80 percent. The calculated dose is to an unsheltered population. For these input parameters, total casualties are calculated to be 16.1 million, 13.3 million of which are fatalities.

should be noted that in NRDC's MAO-NF, we do not attack the 52 silo launch control centers, some or all of which are not co-located with missile silos.

Casualties and Sensitivity Analysis

As we will demonstrate, an attack on the silos represents a far greater threat to Russian civilians and to the environment than an attack on the other seven categories that make up Russia's nuclear forces. Figure 4.4 shows the fallout patterns that result from our MAO-NF attack on all active Russian silos, assuming the most

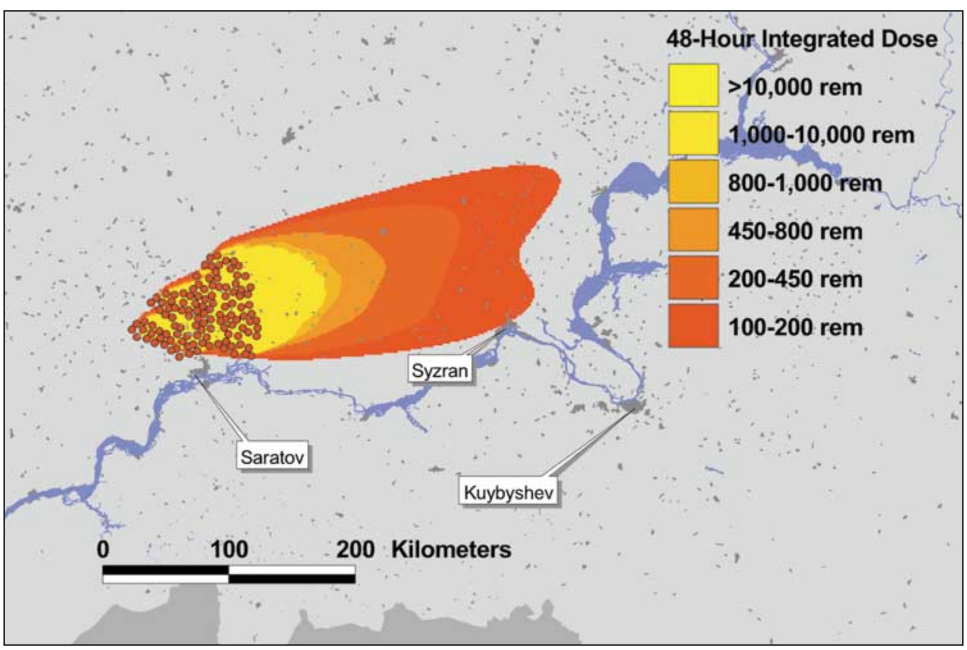
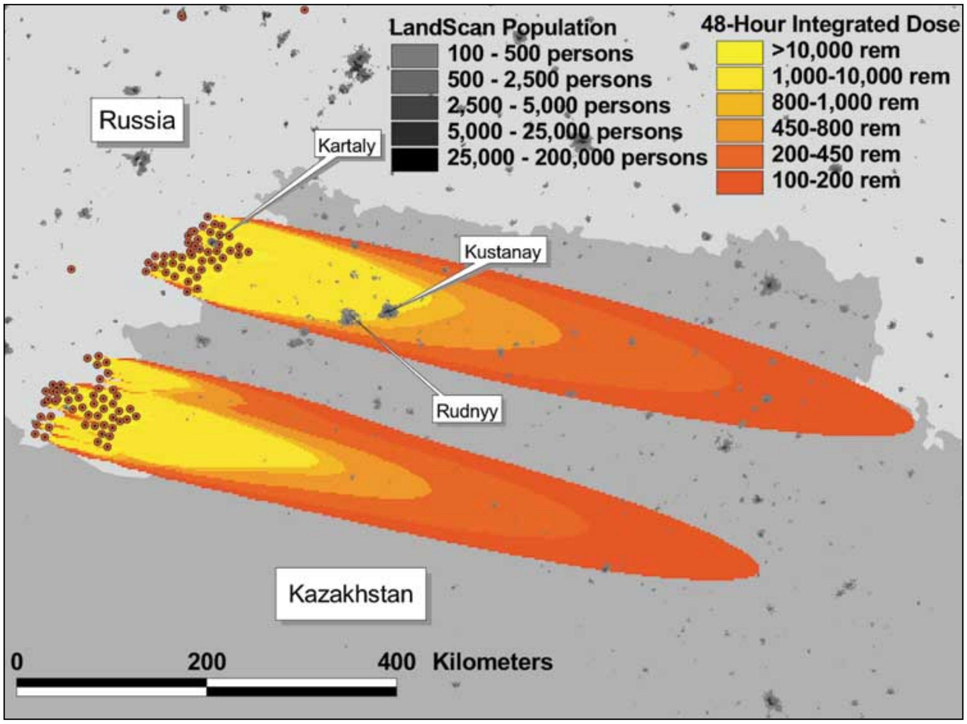


FIGURE 4.12
A Close-up of the Tatishchevo Missile Field Fallout Pattern
Calculated for the month of December and a fission fraction of 50 percent. The calculated dose is to a population sheltered in multi-storied structures. For these input parameters, total casualties are calculated to be 450,000, including 270,000 fatalities.

FIGURE 4.13
A Close-up of Fallout Impacting Kazakhstan
From the attack on the Dombarovskiy and Kartaly missile silos. In this calculation, wind patterns for the month of February and a fission fraction of 50 percent are used, and the calculated dose is to an unsheltered population. For these input parameters, total casualties are calculated to be 977,000, including 745,000 fatalities. The population density, shown in gray, has been overlaid on the fallout patterns. About 60,000 square kilometers in northern Kazakhstan would be contaminated by fallout to such a level that half of unsheltered persons would die as a result.



probable winds for the month of June, a 50 percent fission fraction for all weapons, and an unsheltered population. The vast swaths of fallout spread over 175,000 square kilometers and threaten approximately 20 million Russian civilians. It should be recalled that the purpose of the attack is to destroy 360 missile silos.

Our conclusions about casualties from fallout are affected by the variability of meteorological conditions, population sheltering, and the fission fraction of U.S. warheads. To assess these variations, we have run 288 possible attack scenarios for: the twelve months of the year,[8] three wind conditions,[9] four kinds of sheltering,[10] and two fission fraction percentages.[11] In sum, 288 calculations for each of 360 silos represents 100,800 individual silo fallout calculations. Figures 4.5 through 4.13 present a statistical picture of the Russian casualties and fatalities from the silo attack over this reasonable range of input parameters.

The number of casualties from fallout ranges from 4.1 million to 22.5 million persons assuming no sheltering occurs, and between 1.3 and 15.1 million if all affected people could stay inside residential or multi-story structures for at least two days after the attack (see Figure 4.5). Calculations using the assumption of no sheltering illustrate the total number of civilians at risk. Under the assumption of no sheltering, the number of fatalities from fallout ranges from 3.2 million to 17.6 million persons. If all affected persons could stay inside residential or multi-story structures for at least two days following the attack, that number fatalities drops to between 0.8 and 3.8 million (see Figure 4.6).

The large difference in the number of casualties for a given level of sheltering depends primarily upon the monthly variation in the wind direction and speed. Figure 4.7 displays this variation in casualties by month under the assumptions of a fission fraction of 50 percent and no population sheltering, and Figure 4.8 displays this variation in casualties by month under the assumption of a fission fraction of 80 percent and residential sheltering. We find the maximum number of casualties in the month of June (see Figures 4.7 and 4.8). During this month, the winds blow fallout from the Kozelsk missile field directly towards Moscow. In Figure 4.8, the number of fatalities for June is not appreciably larger than for other months because the assumption of residential sheltering restricts the lethal area to just outside Moscow.

Figures 4.9 and 4.10 show how the number of casualties and fatalities vary with the specific missile field attacked. While considerable seasonal variation exists, attacks against the two missile fields in European Russia (Kozelsk and Tatishchevo) result in larger numbers of casualties, by an order of magnitude, than against the missile fields in Siberia because of the greater population in the vicinity of the missile fields. Figures 4.11 and 4.12 provide close-ups of the fallout patterns over the Kozelsk missile field near Moscow and the Tatishchevo missile field on the Volga River, respectively. Figure 4.13 provides a close-up of the fallout patterns produced from the attack on the missile fields in Siberia, which is calculated to contaminate significant areas of Kazakhstan.

ROAD-MOBILE ICBMS

Description of Targets

The Russian road-mobile ICBM force currently consists of 360 single-warhead SS-25 missiles. Depending upon resources, an improved version of the missile, the Topol-M (SS-27) may replace some SS-25s. [12] The SS-25s are currently mounted on a seven-axle chassis of the MAZ cross-country vehicle. According to the Russian Government:

FIGURE 4.14
A Drawing of Deployed Russian SS-25 Launchers
Source: *Soviet Military Power.*[13]

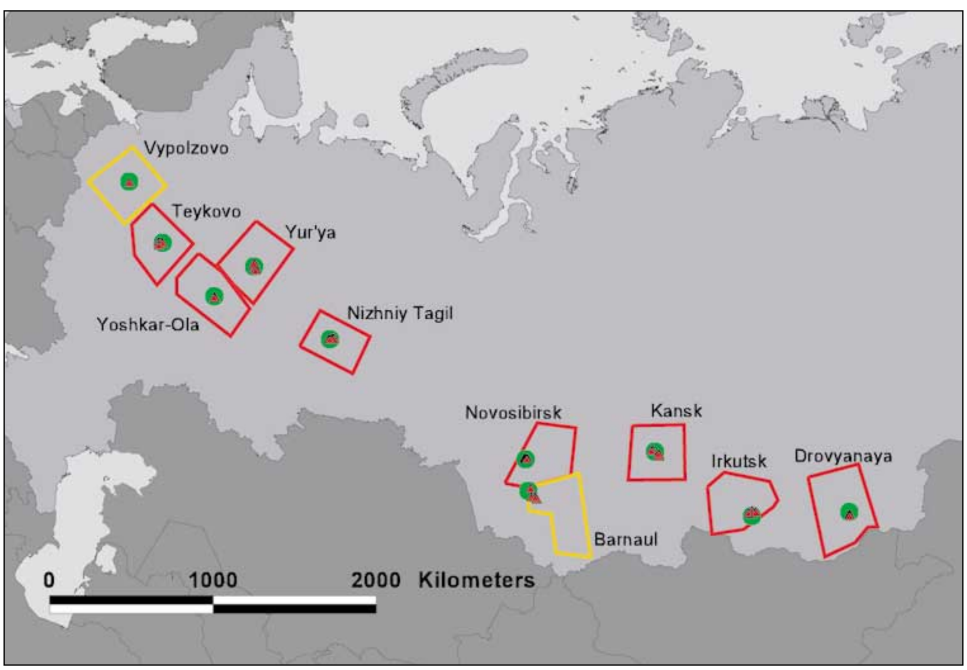
The road-mobile launcher can operate either autonomously or as part of the road-mobile missile complex. Special Krona shelters with hinged roofing are provided in permanent garrisons for missile launching from autonomous road-mobile launchers. The missile can also be launched from unprepared launching sites if the terrain relief allows.[14]

Figure 4.14 is a depiction by the Pentagon of SS-25 transporter-erector-launcher (TEL) vehicles dispersing from their garrison in groups of three. Also shown are two communications vehicles (displaying long antennas) and another vehicle, probably a personnel carrier.

Whereas the SS-25 disperses to the field in groups of three, in garrison they are organized in groups of nine.[15] The Krona shelters at the garrisons have been described as having, "fixed concrete structure foundation[s]."[16] Some SS-25 bases are former SS-20 intermediate-range ballistic missile bases (the SS-20 was eliminated under the 1987 Intermediate-Range Nuclear Forces Treaty). The START I MOU refers to the garrisons as "restricted parking areas." The treaty provides the coordinates for 40 restricted parking areas associated with ten SS-25 bases: Barnaul,[17] Drovyanaya, Irkutsk, Kansk, Nizhniy Tagil, Novosibirsk, Teykovo, Vypolzovo, Yoskkar-Ola, and Yur'ya. The START I MOU also specifies large "deployment areas" associated with the ten bases, presumably roaming areas for the MAZ vehicles. The locations of the SS-25 bases, restricted parking areas (or garrisons), and deployment areas are shown in Figure 4.15.

Figure 4.16 indicates the locations of the Teykovo SS-25 garrisons and the main operating base superimposed on a map of the area. Note the rail spur terminating at the location of the base.[18] The Teykovo garrisons are separated by 15-25 kilometers. Figure 4.17 is a map of the Irkutsk SS-25 garrisons and the main operating base. Figure 4.18 is a recent Ikonos satellite image of two Yur'ya garrisons.

FIGURE 4.15
SS-25 Bases, Garrisons, and Deployment Areas
Bases (green circles), garrisons (red triangles), deployment areas (orange and red polygons). Base locations, garrison locations, and deployment areas shown in red are from the July 2000 START I MOU. Deployment areas shown in orange are notional.



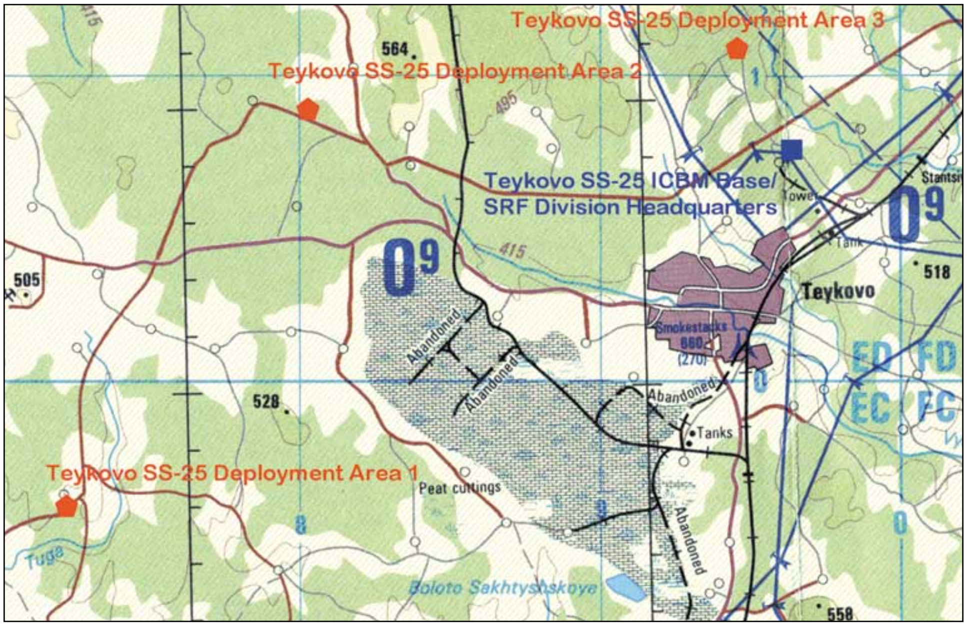


FIGURE 4.16
Teykovo SS-25 Garrisons and Main Operating Base
Source: U.S. JOG N037-12 (Series 1501 Air, Edition 3, "Map Information as of 1993").

Warhead Requirements and Aimpoints

In general there are five kinds of targets associated with Russia's road-mobile ICBMs:

- The hardened organizational and/or communications structures located at the ten regimental bases
- The 360 Krona shelters in the 40 garrisons near the associated bases
- Any of the 120 groups of three MAZ ICBM launcher vehicles that may disperse during a crisis
- Any dispersal (secondary) bases within the deployment areas

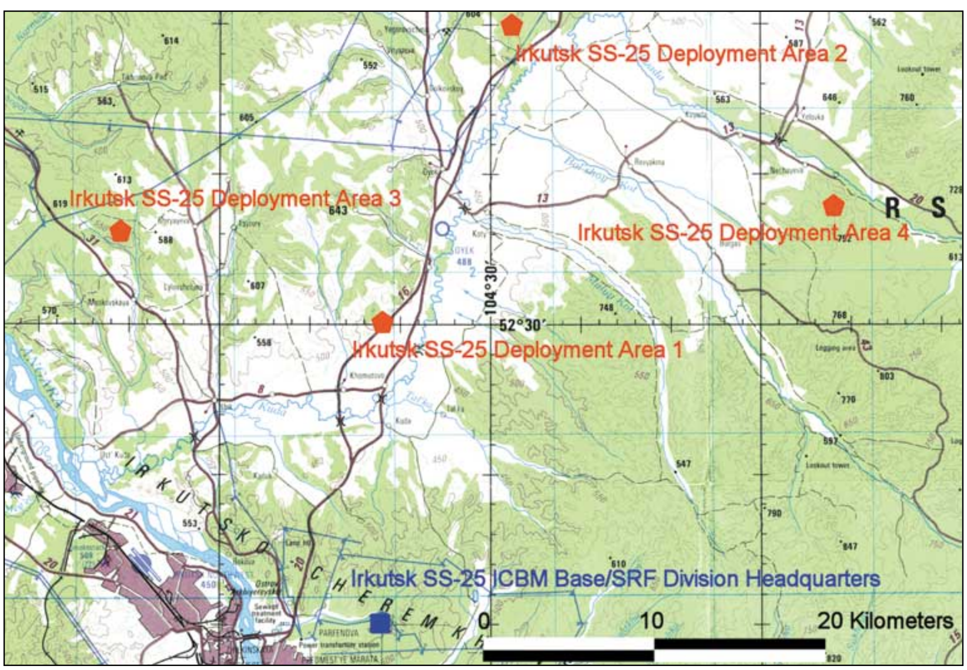


FIGURE 4. 17
Irkutsk SS-25 Garrisons and Main Operating Base
Source: U.S. JOG NN48-11, Series 1501, Edition 2, "Compiled in 1984."

▶ Any air defense sites intended to protect dispersed MAZ launcher vehicles or the garrisons from U.S. bomber/cruise missile attacks

Targeting dispersed SS-25s is difficult. The 1988 edition of the U.S. Defense Department's *Soviet Military Power* refers to the SS-25 as "inherently survivable," its very purpose from the Soviet point of view. Allocating warheads to dispersed SS-25s depends upon the capability to locate them. Increasing the chances depends upon several factors. First, intelligence about past dispersals during training exercises may reveal preferred routes, refueling points, and backup bases. In a crisis, military commanders would probably be reluctant to disperse the SS-25s in alternate ways. Second, there may be some U.S. capability to monitor the locations of the MAZ vehicles in real time. A group of three large SS-25 transporter-erector-launchers, and their support vehicles, would be obvious in high-resolution satellite imagery or aerial photography. Third, monitoring communications between SS-25s in the field and command centers may reveal their locations.

The 1969 Defense Intelligence Agency *Physical Vulnerability Handbook—Nuclear Weapons* assigns a vulnerability number of 11Q9 to road-mobile missiles with ranges of 700, 1,100, and 2,000 nautical miles or with intercontinental ranges.[19] The damage level for this vulnerability number is defined as "transporter overturned and missile crushed." [20] The kill mechanism has been likened to flipping a turtle on its back. For a 100-kt weapon, the optimum height of burst to attack a target with a vulnerability number of 11Q9 is approximately 1,250 m (no local fallout would be expected), and the corresponding damage radius is 2,875 m. Thus dispersed SS-25 vehicles can be threatened over an area of approximately 26 square kilometers by a single W76 air burst. If, for example, a MAZ vehicle is traveling at 20 kilometers per hour, then one W76 explosion must occur within about 15 minutes of noting the location of the moving vehicle. While this time interval is roughly consistent with depressed-trajectory launches of SLBMs, it would require additional time to communicate the SS-25 locations to the SSBNs and retarget the missiles. The fact that Trident I or Trident II SLBMs are MIRVed, with up to eight warheads per missile, means that a group of moving SS-25 launcher vehicles could also be pattern-attacked with W76 warheads over an area of some 200 square kilometers.

Alternatively, field-dispersed SS-25 vehicles may be sought out and destroyed by long-range

FIGURE 4.18
Ikonos Satellite Image of Two SS-25 Garrisons at Yur'ya
The garrisons are the square, fenced structures in upper and lower left. The resolution in this image—taken March 24, 2000—is approximately 16 meters. Source: spaceimaging.com.

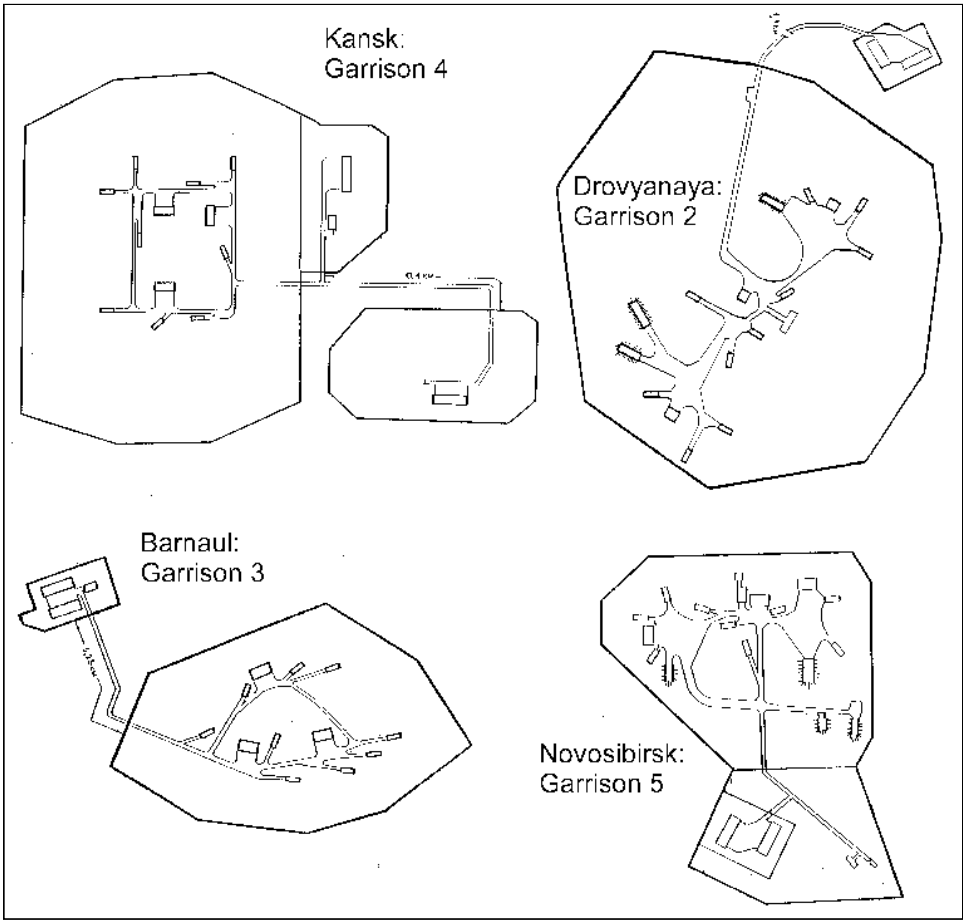


FIGURE 4.19
Diagrams of SS-25 Road-Mobile Garrisons
Source: INF Treaty data declaration. Drawings are reproduced to the same scale, 1:17,500.

strategic bombers, like the B-2. Given that the SS-25 ICBM carries only one warhead of probably limited accuracy, it is reasonable to expect that Russian planners treat it as a countervalue weapon. A recently declassified CIA document lists it as such.[21] If SS-25's are part of Russia's strategic reserve, intended to be held back to deter or carry out subsequent nuclear attacks, then it is likely that Russia would take a great effort to conceal at least a portion of them from U.S. strategic bombers on search-and-destroy missions.

The START I MOU data exchange provides information about the 40 SS-25 garrisons. The areas of the garrisons range from 0.1 km^2 to 0.45 km^2, with an average area of 0.275 km^2. The earlier INF data exchange contained diagrams of SS-20 garrisons at the Kansk, Barnaul, Novosibirsk, and Drovyanaya operating bases. In these diagrams—a sample of which is displayed in Figure 4.19—the Krona shelters are shown as rectangles, approximately 30 by 10 meters in size.

We do not have the specific vulnerability numbers (VN) associated with the individual SS-25 Krona shelters.[22] Therefore, we assume that the Krona shelters are either "aboveground, flat or gable roof, light-steel-framed" structures, where the VN for severe/moderate damage are given as 13Q7/11Q7, or "aboveground, arch, earth-mounded, drive-in" shelters, where the VN for severe/moderate damage are given as 26P3/25P1.[23] The vulnerability for the first of these two structure types (light-steel-framed) is given in terms of the dynamic pressure, which relates to the

TABLE 4.3
Attacking Two Types of SS-25 Garrison Structures

Structure Type	Attacking Warhead Yield (kt)	Optimum Height of Burst (m)	Damage Radius (m)	Mean Area of Effectiveness (km^2)
Steel-framed	100	1,000	1,990	12.4
Earth-mounded	100	0	503	0.79
Steel-framed	300	1,600	3,121	30.6
Earth-mounded	300	0-200	745	1.7
Steel-framed	475	1,900	3,750	44.2
Earth-mounded	475	0-300	876	2.4

wind velocity produced in the explosion.[24] The vulnerability number given for the earth-mounded structure implies a high damage threshold with respect to peak blast overpressure.[25]

Table 4.3 shows the optimum height of burst, damage radii, and mean area of effectiveness (i.e., π multiplied by the damage radius squared) for two types of structures—steel-framed and earth-mounded—when attacked by W76 (100 kt), W87 (300 kt) or W88 (475 kt) warheads. Note the mean area of effectiveness of the lowest-yield warhead (the W76) against the harder structure type (earth-mounded) is about twice the area of any SS-25 garrison. For the more vulnerable, steel-framed structure, any of the three warhead types are capable of destroying all of the Krona shelters in a garrison, but the damage radii are less than one-fifth the separation distance between any of the SS-25 garrisons associated with a main base. Therefore, even if 300-kt or 475-kt warheads are used, one warhead would have to be allocated per

Table 4.4
Probabilities of Achieving Severe and Moderate Damage as a Function of the Separation Between the Explosion and the Target for the Earth-Mounded Structure Type Associated with SS-25 Garrisons
For the W76 ground bursts, two values of the CEP are given, corresponding to Trident I (183 meters) and Trident II (130 meters).

Distance from Ground Zero to Target (m)	C.E.P. (m)	Probability of Achieving Severe Damage for a VN of 26P3: earth-mounded structures)	Probability of Achieving Moderate Damage (for a VN of 25P1: earth-mounded structures)
0	130	0.996	0.997
0	183	0.979	0.985
100	130	0.990	0.993
100	183	0.966	0.973
200	130	0.957	0.969
200	183	0.914	0.931
300	130	0.865	0.891
300	183	0.805	0.835
400	130	0.676	0.725
400	183	0.631	0.675

garrison. One important difference between the two bounding vulnerability assumptions is that if the Krona shelters are steel-framed, the attacking warhead would be detonated at an optimum height of burst that would preclude local fallout.[26]

Table 4.4 lists the probability of achieving severe damage by a W76 ground burst to an earth-mounded Krona shelter as a function of the separation between the explosion and the shelter. These calculations reveal that even if the Krona shelters have been hardened to this level, two W76 ground bursts near the center of the garrison would be sufficient to destroy the Krona shelters with a high probability, as they are arrayed within several hundred meters of the garrison center. The assumption that the Krona shelters are earth-mounded necessitates ground bursts for attacking W76 warheads.

Given this vulnerability analysis, we choose for MAO-NF an SLBM attack using 100-kt W76 warheads, limited to the road-mobile SS-25's operating base and garrison targets. We assign two W76 ground bursts to each of the ten SS-25 operating bases and 40 garrisons.[27] In all, we use 100 W76 warheads with a cumulative yield of ten megatons. We do not target dispersed road-mobile launchers in our MAO-NF because our current scenario is limited to U.S. launch-ready weapons (which today excludes the U.S. strategic bomber force), and because targeting dispersed SS-25's with ICBM or SLBM warheads appears problematic.

Casualties and Sensitivity Analysis

Our quantitative assessments about damage and casualties are affected by the variability of meteorological conditions, and our assumptions regarding population sheltering, and the fission fraction of U.S. warheads. To assess these meteorological variations and uncertainties we have performed 288 calculations for each of the

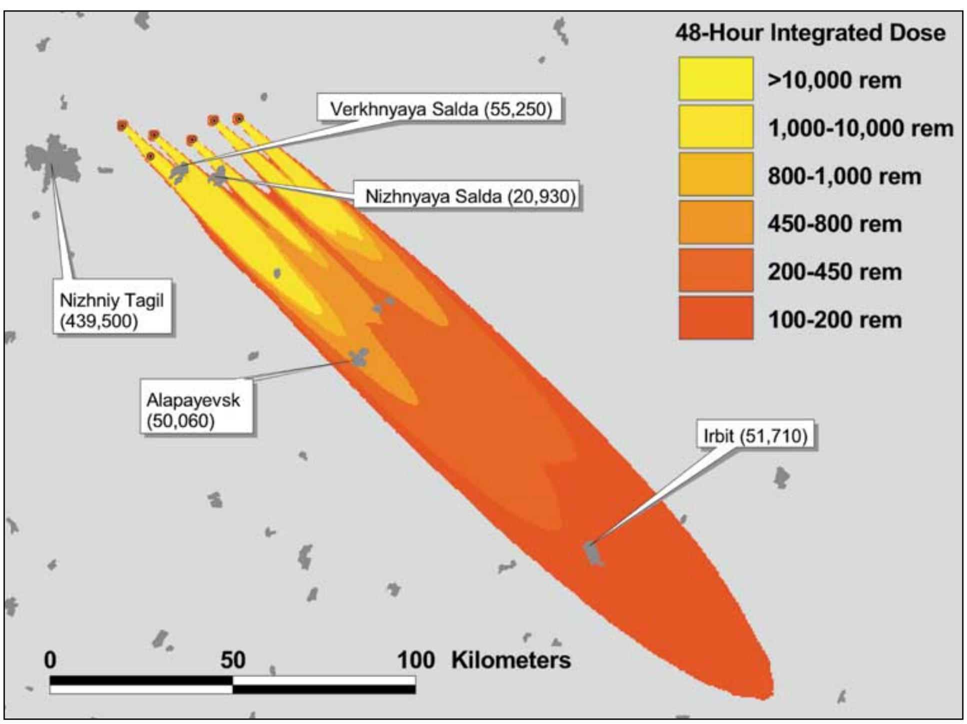
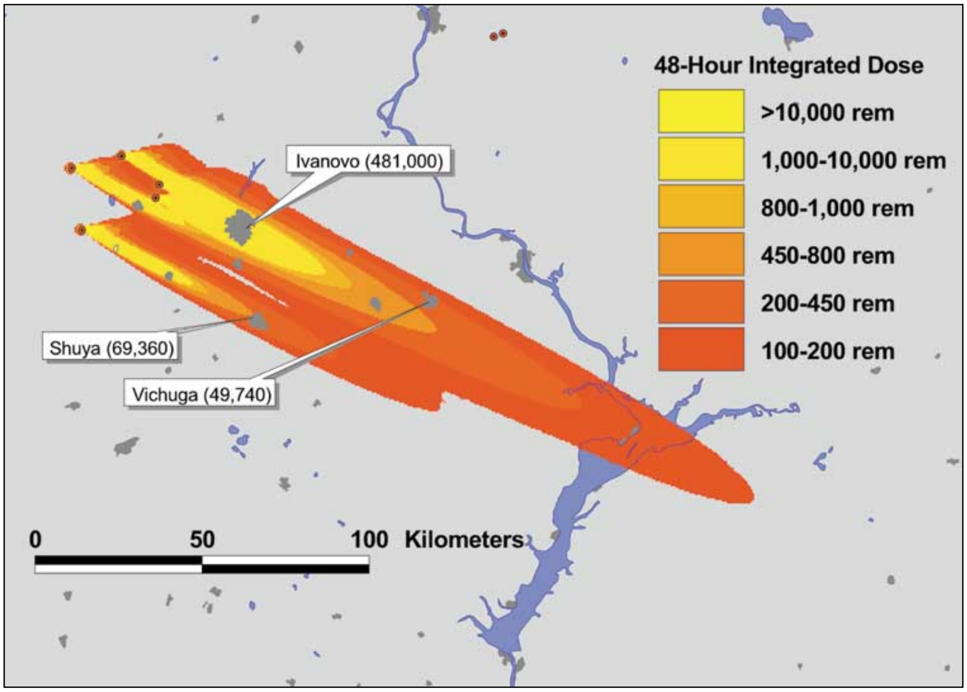


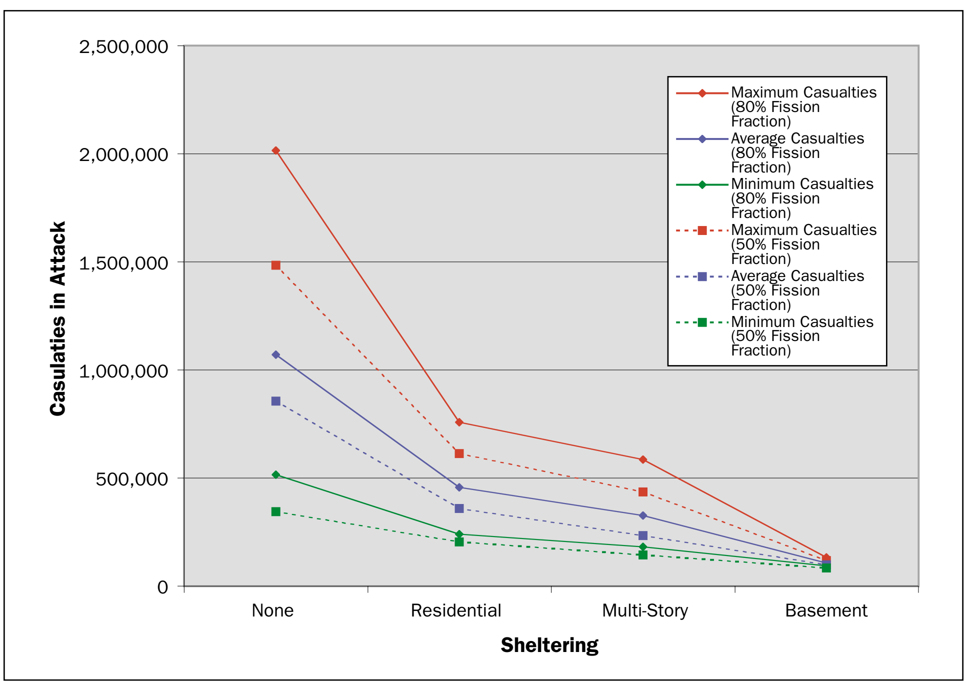
FIGURE 4.20
Twelve-Warhead Attack on the Nizhniy Tagil SS-25 Garrisons and Base
For the month of November, assuming an unsheltered population and a warhead fission fraction of 80 percent. The total number of casualties is computed to be 162,000, 132,000 of which are fatalities.

FIGURE 4.21
Twelve-Warhead Attack on the Teykovo SS-25 Garrisons and Base
For the month of December, assuming an unsheltered population and a warhead fission fraction of 80 percent. The total number of casualties is computed to be 804,000, 613,000 of which are fatalities.



SS-25 bases and garrisons.[28] The number of casualties depends upon the proximity of the targets to major urban areas. To illustrate the variation, we compare an attack using W76 warheads on the Nizhniy Tagil SS-25 site and on the Teykovo SS-25 site. Figure 4.20 shows the effects of twelve surface bursts on the SS-25 Nizhniy Tagil garrisons and base. The Russian city of Nizhniy Tagil (1989 population 439,500) is located only 22 kilometers from the nearest SS-25 garrison, yet the most probable

FIGURE 4.22
Summary Casualty Data for an Attack on Russian SS-25 Garrisons and Bases
Casualties are plotted as a function of population sheltering and warhead fission fraction. Variations in the number of casualties for a given warhead fission fraction and population sheltering reflect seasonal variations in the most probable wind speeds and directions.



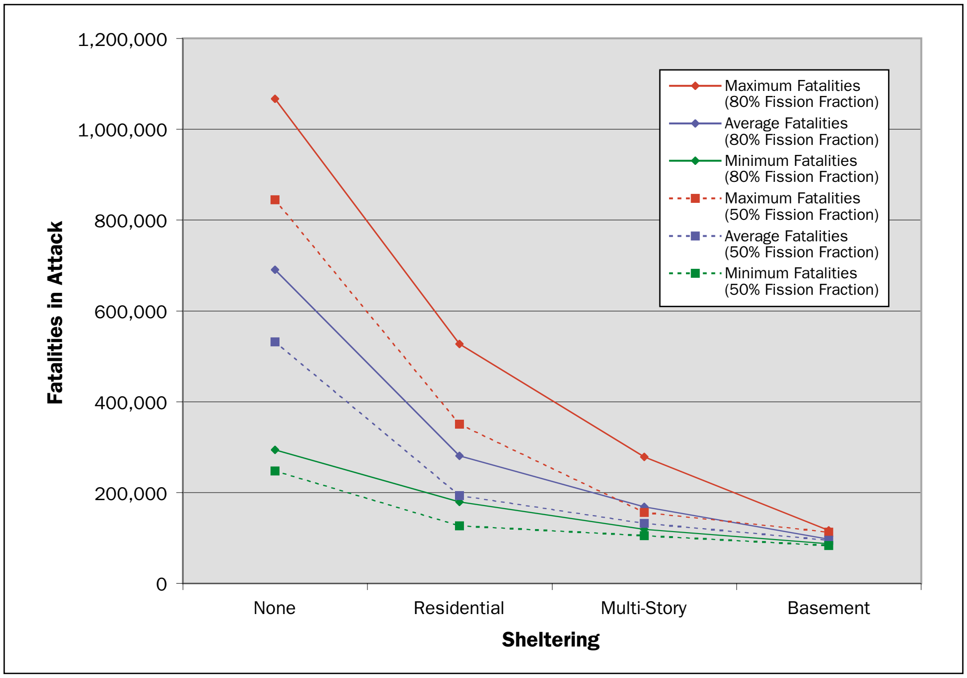


FIGURE 4.23
Summary Fatality Data for an Attack on Russian SS-25 Garrisons and Bases
Fatalities are plotted as a function of population sheltering and warhead fission fraction. Variations in the number of fatalities for a given warhead fission fraction and population sheltering reflect seasonal variations in the most probable wind speeds and directions.

wind patterns for all months of the year blow the fallout away from the city. Nevertheless several smaller cities lie in the path of the descending fallout and the computed casualties for an unsheltered population (and assuming a fission fraction of 50 percent) vary from 47,000 to 171,000 people, with fatalities ranging from 45,000 to 113,000 depending on the month. If in the unlikely event the fallout blew over the city of Nizhniy Tagil, the number of casualties would be four to six times higher. By contrast, as shown in Figure 4.21, the fallout from a W76 attack against the Teykovo SS-25 base/garrison creates lethal conditions within the city of Ivanovo (1989 population 481,000) itself, causing many more casualties.

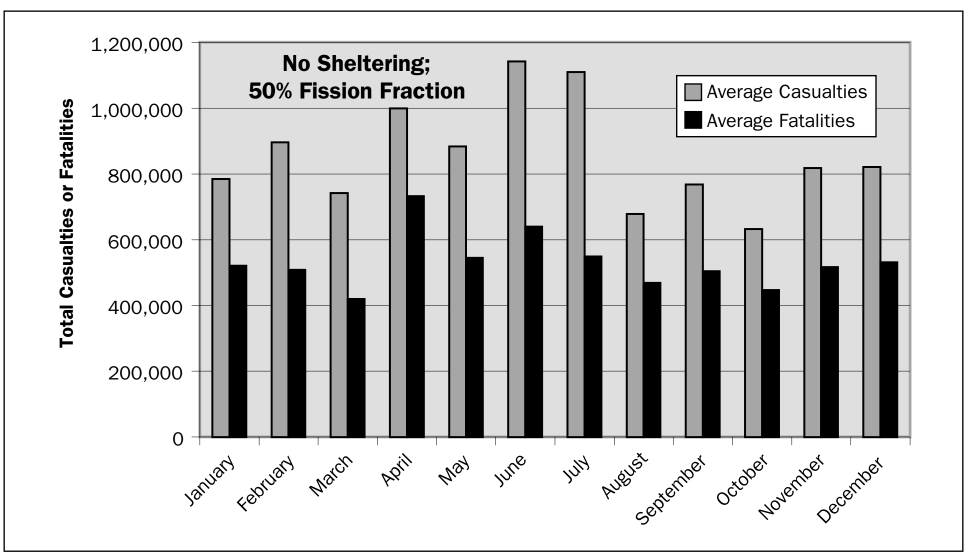
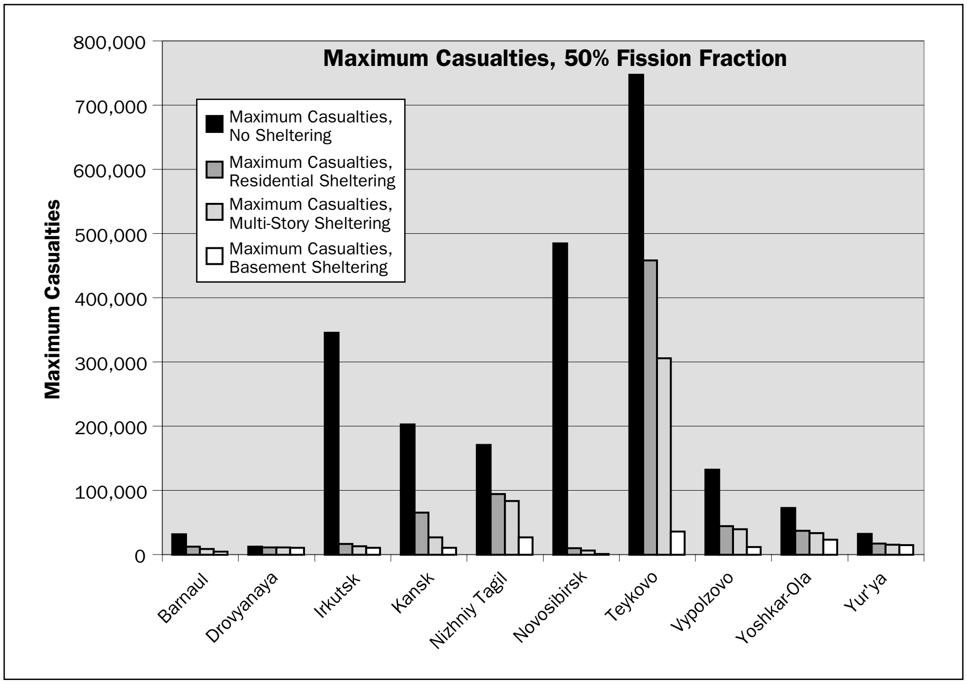


FIGURE 4.24
Casualties as a Function of the Month of the Year for an Attack on Russian SS-25 Garrisons and Bases
These variations are due to wind speed and direction. Casualties and fatalities have been averaged with respect to the angular resolution of the wind rose data (see Endnote 7).

FIGURE 4.25
Maximum Casualties Associated with Each Road-Mobile Garrison/ Base Complex
As a function of population sheltering for a warhead fission fraction of 50 percent.



Figures 4.22 and 4.23 show the range of casualties and fatalities due to seasonal variations in wind speed and direction as a function of population sheltering and warhead fission fraction for the full attack of 100 W76 warheads against the 50 SS-25 targets. The figures show that total casualties or fatalities depend more on the population sheltering than on the warhead fission fraction, but both parameters are significant. The total number of casualties ranges from 344,000 to 2 million persons assuming no sheltering occurs, and between 142,000 and 757,000 if all affected persons could stay inside residential or multi-story structures for at least two days following the attack. Under the assumption of no sheltering, the number of fatalities from fallout ranges from 244,000 to just over one million persons. If all affected people could stay inside residential or multi-story structures for at least two days following the attack, that number of fatalities drops to between 105,000 and 527,000.

Figure 4.24 shows how monthly variation in wind patterns influences the number of casualties. Figure 4.25 displays maximum casualties for individual base/garrison complexes for the four values of sheltering factors used in these calculations. For most of the SS-25 base/garrison complexes, notably Irkutsk and Novosibirsk, even sheltering in residential structures for the first two days following the attack would drastically reduce the computed number of casualties from the fallout.

RAIL-MOBILE ICBMS

Description of Targets

Each of Russia's 36 rail-mobile SS-24 ICBMs carries ten 550-kt warheads, for a total of 360 high-yield warheads. According to the Russian government these weapons are part of:

FIGURE 4.26
A Drawing of an SS-24 Train and Missile
Source: *Soviet Military Power.*[29]

> *A sophisticated complex, which carries the missile, technological equipment, special-purpose systems, the attending personnel, as well as the command and control equipment. . . . A rail-mobile missile regiment incorporates a train with three rail-mobile launchers carrying the RS-22V [i.e., SS-24] missiles, a command post, railway cars with auxiliary and personnel life support systems.*[30]

The rail-mobile ICBMs either remain stationed at a permanent location (see Figure 4.26) or move over the railway tracks. The missile can be launched from any point.

According to the July 2000, START I MOU data exchange between the U.S. and Russia, there are 36 deployed SS-24 ICBMs presumably on 12 trains at three bases:

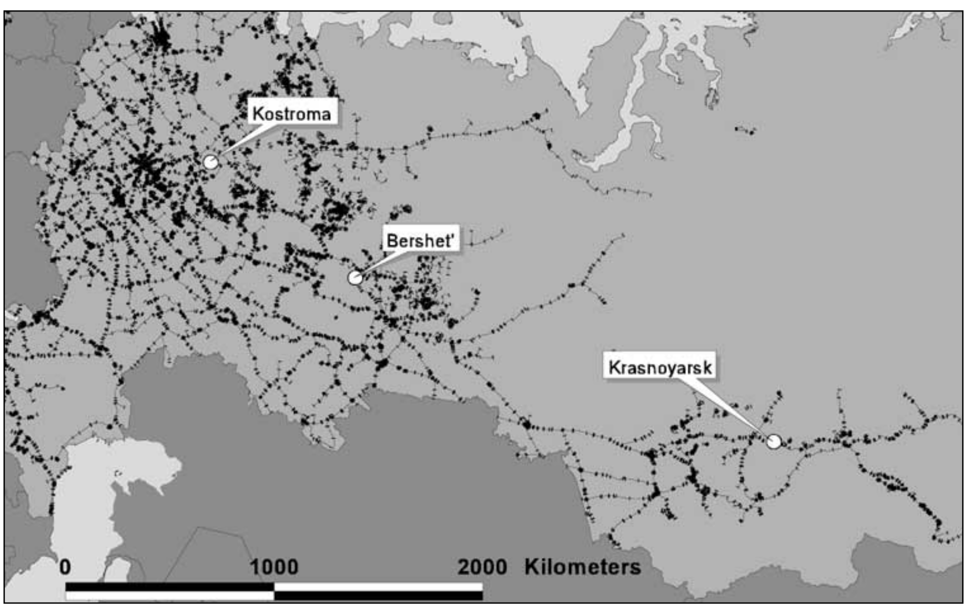
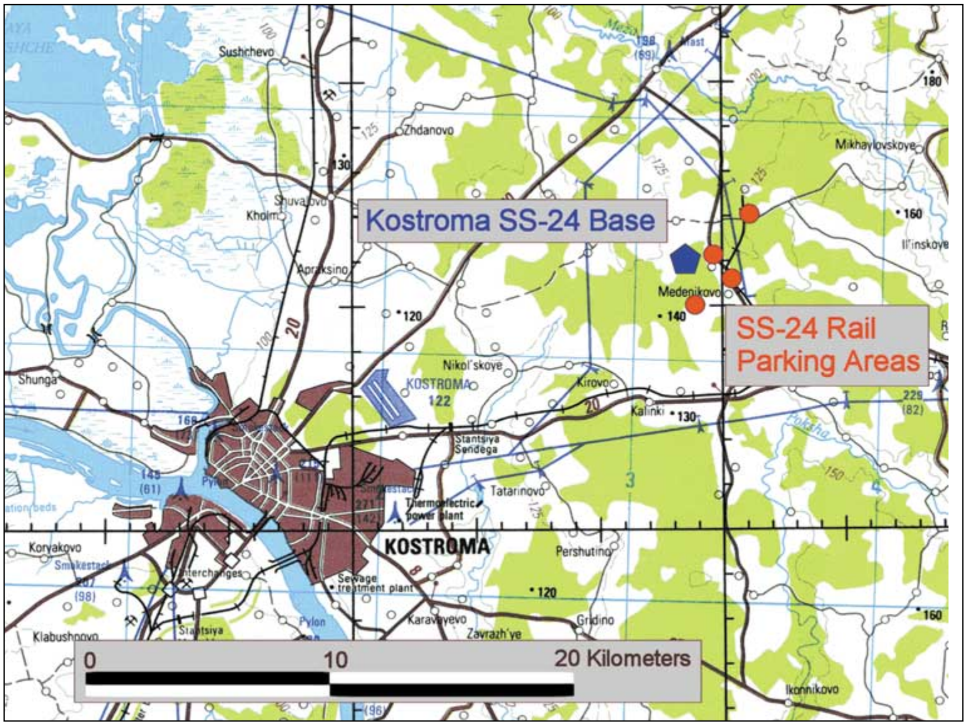


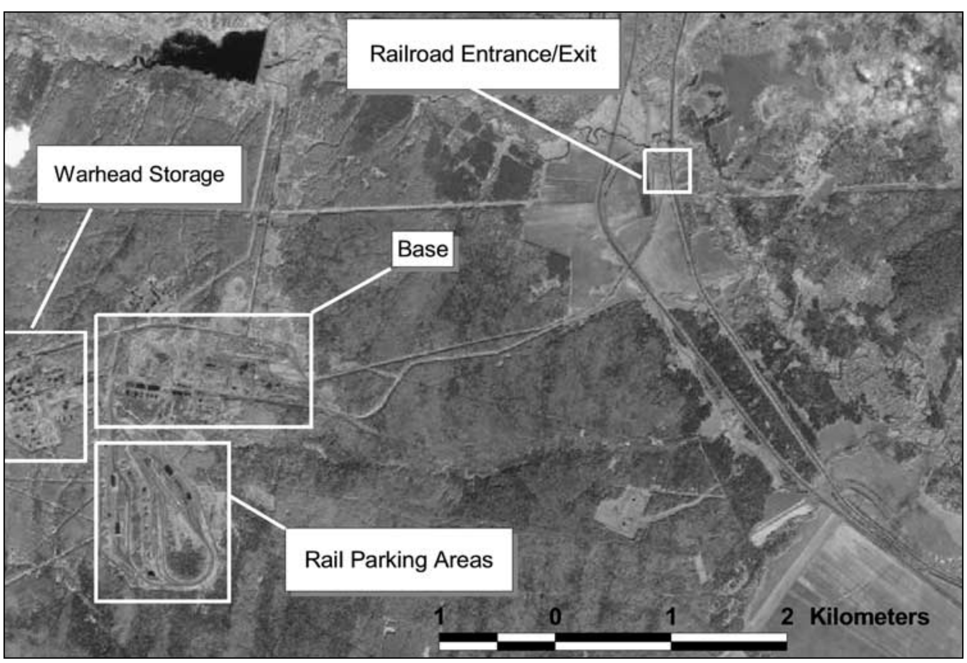
FIGURE 4.27
Russia's Railroad Network and the Three SS-24 Rail-Mobile ICBM Bases

FIGURE 4.28
Kostroma Rail-Mobile ICBM Base
In 1989, the city of Kostroma had a population of 278,400. Source: U.S. JOG NO 37-9, Series 1501, Edition 2, "Compiled in 1982."



Bershet', Kostroma, and Krasnoyarsk. Figure 4.27 shows the locations of the three bases overlaid onto the Russian rail network. The START data gives coordinates for four rail parking areas and one railroad exit/entrance point associated with each of the three SS-24 bases. Figure 4.28 displays the START data for the Kostroma SS-24 base superimposed on a U.S. JOG. The base is located along a rail spur close to what is a major city in European Russia.

FIGURE 4.29
An Ikonos Satellite Image of the Bershet' Rail-Mobile ICBM Base
This image was taken on July 22, 2000: 16-meter resolution shown). Source: spaceimaging.com.



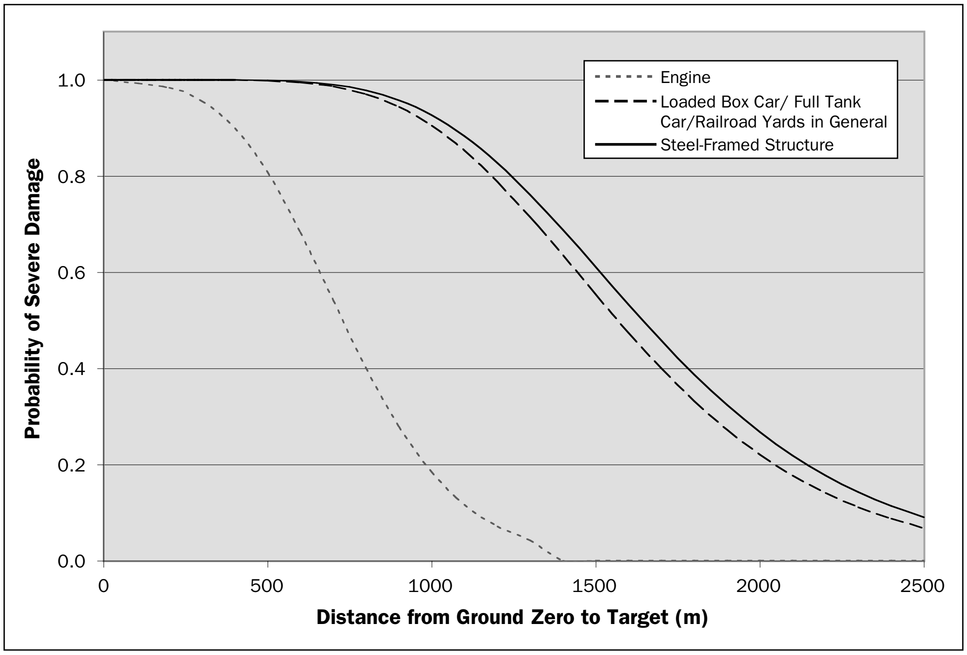


FIGURE 4.30
Probability of Severe Damage to Light Steel-Framed Structures, Loaded Box Cars/Full Tank Cars, and Engines
As a function of distance between ground zero and target. For this calculation we use the vulnerability numbers given in Table 4.5, and use a yield of 100 kt, a HOB of 500 meters and a C.E.P. of 184 meters.

Figure 4.29 is an Ikonos satellite image (16-meter resolution) displaying the Bershet′ SS-24 base. The superimposed white rectangles are from the START MOU. The fact that the rail parking areas are several hundred meters south of the declared START locations reflects the imprecision of the START MOU coordinate data—where latitude and longitude are given to the nearest minute.[31]

Warhead Requirements and Aimpoints

The rail-mobile SS-24 poses a similar targeting problem to the road-mobile SS-25. The SS-24s can be launched whether at their bases or at any point on Russia's rail

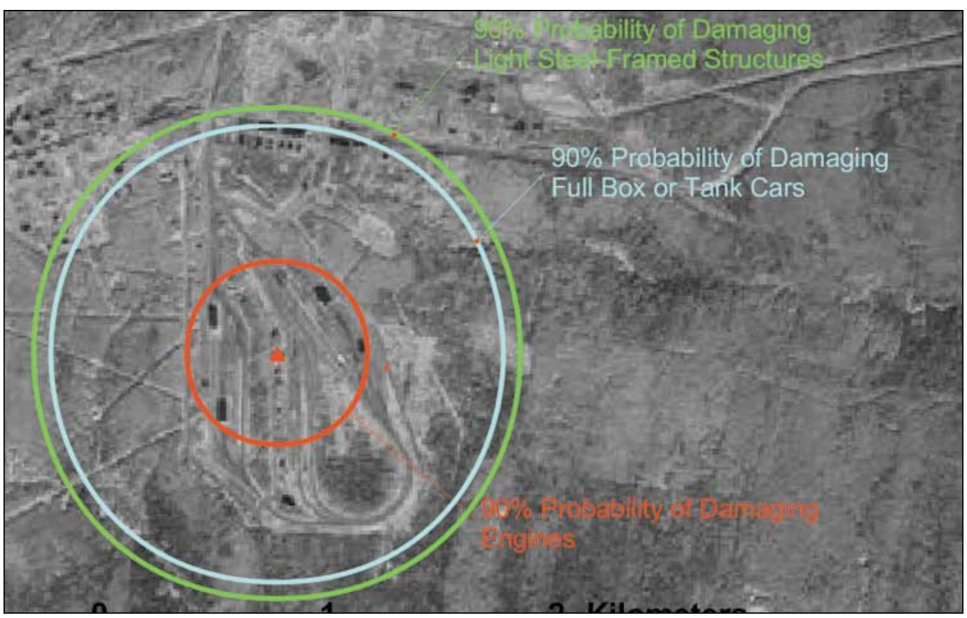


FIGURE 4.31
Damage Probability Contours for the Specified Target Types at the Bershet' Rail-Mobile SS-24 Base
Source: spaceimaging.com.

lines. There may also be dispersed parking sites for SS-24 trains when they are not at the main base. Table 4.5 lists vulnerability numbers associated with rail systems. The NTDI Handbook lists the SS-X-24 ICBM as a type of missile system in the category of surface-to-surface missile sites. The NTDI Handbook also lists a light-steel-framed structure as one of the missile-ready structures for this target category, and this structure type is apparently that shown in Figure 4.26. Note that the dynamic pressure required to damage locomotives is substantially greater than for other rail components, and according to the NTDI Handbook it is necessary to crater railroad tracks in order to damage them.

Figure 4.30 plots the probability of achieving severe damage to three of the items in Table 4.5 as a function of distance between ground zero and target for a 100-kt air burst at 500 meters HOB. Figure 4.31 shows the distance at which 90 percent probability of severe damage is achieved to these rail components superimposed on a close-up of the Ikonos image of the SS-24 base at Bershet'. It is clear that one W76 air burst is sufficient to damage the trains, cars, and associated

TABLE 4.5
Nuclear Weapons Vulnerability Data for Rail Systems
Source for the Vulnerability Numbers: *NATO Target Data Inventory Handbook* (1989).

Item	Vulnerability Number	Dynamic Pressure (psi) for 100 kt Air Burst (HOB=500m)	Damage Radius (m) for 100 kt Air Burst (HOB=500 m)	Damage
Railroad yards in general	13Q5	2.5	1,723	Severe damage to the installation consisting of grave damage to rolling stock requiring essentially complete replacement and severe damage to most types of contents, and associated damage generally as follows: severe track blockage; severe structural damage to single-story transit sheds and maintenance shops; overturning of control and switch towers; light damage to locomotive tenders; and moderate to severe damage to electric power facilities and other aboveground utilities.
Aboveground, flat or gable roof, light-steel-framed [structure type]	13Q7	2.2	1,806	Severe damage: failure of one or more structural elements (roof, wall, or closure) enclosing protected spaces that house missiles, equipment, and/or personnel and causing damage to contents by crushing, translation impact due to overpressure, or impact by collapse of a structural element and associated damage generally as follows: physical damage to associated equipment located at the launch site to such extent that the items are rendered inoperative and require major repair.
Loaded box cars	13Q5	2.5	1,723	Severe damage requiring replacement with possible exception of the trucks. Contents damaged beyond salvage point except heavy iron casings or the like.
Full tank cars	13Q5	2.5	1,723	Distortion or rupture of tank shell requires major repair or replacement. Tracks may escape serious damage. Loss of contents by leakage or by fire.
Locomotives	21Q5	47.0	807	Forcefully derailed or overturned.
Roadbed and tracks	45Z0	[Crater]	*	Disruption of rail lines by cratering the roadbed, and dislodging and twisting of tracks.

TABLE 4.6
Calculated Casualties and Fatalities from Five 100-kt Air Bursts over Russia's SS-24 Bases
The LandScan population figures are probably indicative of the average density in the vicinity of the bases. The OTA algorithm was used.

SS-24 Base	Casualties	Fatalities
Kostroma (two W76 warheads)	1,219	265
Bershet' (one W76 warhead)	1,042	249
Karsnoyarsk (two W76 warheads)	1,452	784

structures at this base. Using the separation between rail parking spaces given in the START MOU for the other two SS-24 bases, we estimate that in total five W76 warheads would be sufficient to cause severe damage to rail components at all three SS-25 bases.

Casualties and Sensitivity Analysis

At 500 meters height of burst, no local fallout is predicted. Therefore in terms of attacking the rail-mobile SS-24 bases, the calculated casualties are limited essentially to the base personnel, and include 3,700 casualties and 1,300 fatalities (see Table 4.6).

SSBN BASES AND FACILITIES

Description of Targets

In May of 2000, Admiral Vladimir Kuroedov, Commander-in-Chief of the Russian Navy, said the Russian Navy consisted of:

> *Regionally dislocated strategic groups of the North, Pacific, Baltic and Black Sea Fleets, and also the Caspian Flotilla. The regional dislocation of the Russian Navy requires the support and development of their independent structures, ship-building and ship repair industries. . . . The base of the North and Pacific Fleets is missile strategic and multi-purpose submarines, aircraft-carriers, landing vehicles, naval missile and anti-submarine Air Force. The base of the Baltic, Black Sea and Caspian Fleets is multi-purpose men-of-war, trawlers, diesel submarines, coastal missile and artillery forces and battle Air Force. The special geographical location of some Russian regions requires the presence of ground and anti-aircraft forces within the structure of the Navy.*[32]

The Northern Fleet has responsibility for wartime operations in the Atlantic and Arctic regions as well as for peacetime operations in the Mediterranean.[33]

During the Cold War, the Soviet naval strategy served multiple objectives, including

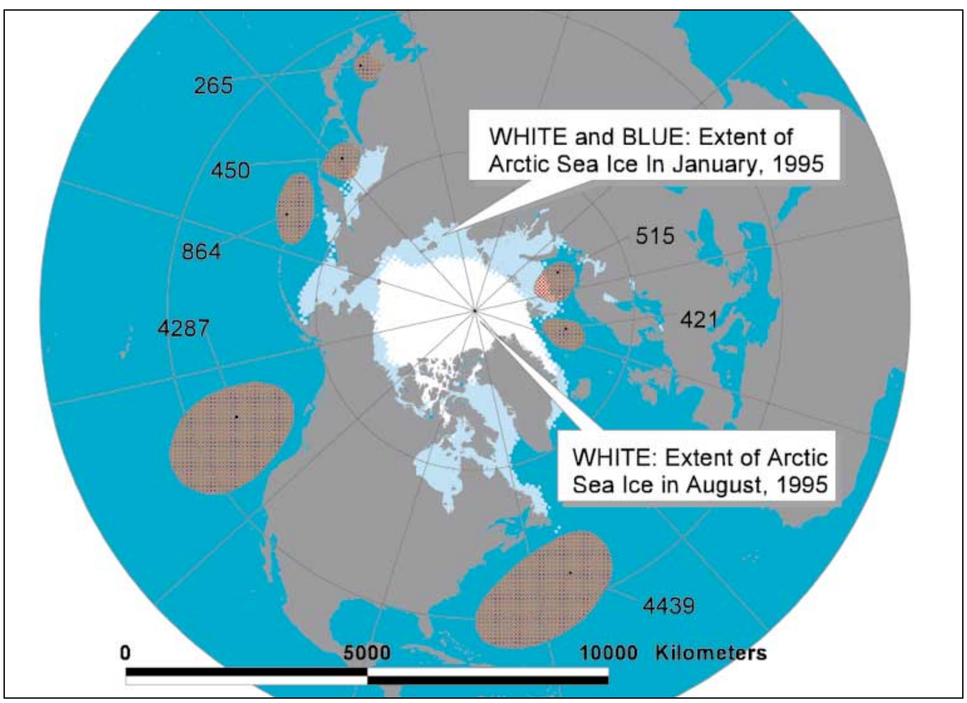
- Deterring nuclear attack by the United States with strategic weapons, such as submarine-launched ballistic missiles (SLBMs) on nuclear-powered ballistic missile submarines (SSBNs); and protecting the SSBNs with naval surface and aviation forces

▶ Controlling the ocean areas contiguous to the Soviet Union, including the Black Sea, the White Sea, the Sea of Japan and Sea of Okhotsk, and key straits
▶ Preventing strikes by U.S. naval forces against the Soviet Union by seeking out and destroying those forces at sea
▶ Neutralizing U.S. bases, e.g., in the Mediterranean and throughout the Pacific region and Alaska
▶ Attacking allied sea lines of communication, e.g., connecting the United States and NATO [34]

By the early 1960s Soviet SSBNs were already achieving the first objective of deterrence by patrolling the Atlantic Ocean. By the end of the decade, submarines of the Pacific Fleet were on regular patrol as well.[35] The SLBMs initially had a maximum range of 2,400 km, which increased to 7,800 km in the 1970s.[36] Figure 4.32 is a 1987 Pentagon depiction of the patrol areas for Russian SSBNs with the approximate areas in thousands of square kilometers.[37] By the 1970s, the SSBNs were able to threaten the United States from military zones, referred to as "bastions," in seas adjacent to Russia. These areas included the White Sea to the east and south of the Kola Peninsula, and the Sea of Japan, and the Sea of Okhotsk.

The principal trends of the last decade for the Russian Navy have been a sharp decline in the number of patrols, reduced maintenance and training, limited research and production, and the scrapping or sale of dozens of Soviet-built vessels. A recent article in *Jane's Defense Weekly* reports that the Russian Navy's operational readiness might be as low as 10 percent.[38] With respect to the Pacific Fleet, for example, the following selected events from the year 2000 reveal the pervasive problems confronting the Russian navy today:

FIGURE 4.32
Soviet SSBN Patrol Areas circa 1987
With the approximate areas in thousands of square kilometers.



- In January 2000, four Russian sailors and a retired officer were arrested for stealing radioactive fuel from a Pacific Fleet strategic submarine in Kamchatka. A search of their apartments turned up submarine parts and equipment, some containing gold, silver, platinum, and palladium.[39]
- During naval exercises on April 10, 2000, the Russian destroyer *Burnyy* fired ten anti-aircraft shells into the left side of the *Admiral Vinogradov*, a large Russian anti-submarine vessel, producing a hole above the waterline.[40]
- In March 2000, five Pacific Fleet sailors suffocated in a submarine compartment, which they had entered in order to collect metal to sell for scrap. The accident occurred in Chazhma Bay.[41]
- In a letter to the governor of Kamchatka, acting commander of the nuclear submarine fleet Rear Admiral Yuri Kirillov stated that military communication lines between the fleet command and nuclear submarines were being disrupted by thieves who were stealing the cables to sell for scrap. "We are desperately losing this war and many units are on the brink of losing their fighting efficiency."[42]
- On April 28, 2000, a military court severely sentenced Pacific Fleet Rear Admiral Vladimir Morev for attempting to sell air defense artillery radar equipment to Vietnam.[43]
- On June 16, 2000, leaked ballistic missile fuel at the Nakhodka naval base formed a toxic cloud (containing nitric acid), which hovered over the town of Fokino, affecting perhaps a dozen people.[44] In the Primorye region, a total of some 2,500 metric tons of missile fuel are currently stored in deteriorating tanks, and funds are not available to send most of this material to recycling plants in western Russia.[45]
- According to a high-ranking military source in the Pacific Fleet, fleet commanders had power for only a few hours per day because of electricity outages. "Data transmission units" were down for nine hours per day and submarine crews were reduced to preparing meals with wood fires.[46]
- The crew of a Japanese fishing boat near the island of Hokkaido spotted a huge, floating metal object on July 26, 2000, bearing the Russian word "inflammable" on an exposed piece. The object turned out to be an antenna, which was part of a Pacific Fleet anti-submarine warning system. It broke off during an earthquake in 1994 and Russian sailors had been searching for it ever since.[47]
- In Vladivostok on July 29, 2000, the entire crew of the BDK-101 large-assault ship abandoned their posts and went ashore to the Pacific Fleet Headquarters to ask for protection from their commanding officer. The crew claimed that they were "constantly beaten, badly fed, punished without cause and forced to work at all hours."[48]
- Due to an acute shortage of fuel, the July 30, 2000 Navy Day parade of ships in Vladivostok was canceled—a first in the history of the Pacific Fleet.[49]
- On September 14, 2000, the destroyer *Admiral Panteleyev*, one of Russia's largest anti-submarine warships, accidentally fired a 100 mm shell at a town in the Khasansk region during a Pacific Fleet exercise. The explosion produced a crater 1.5 meters deep approximately 200 meters from the town of Slavyanka. Reportedly one senior citizen suffered a concussion.[50]

In January 2000, four Russian sailors and a retired officer were arrested for stealing radioactive fuel from a Pacific Fleet strategic submarine in Kamchatka. A search of their apartments turned up submarine parts and equipment, some containing gold, silver, platinum, and palladium.

▸ On October 13, 2000, the Russian Navy command decided to disband one of three submarine combined units of the Pacific Fleet's Maritime Territory Flotilla for lack of funds. The unit of some two-dozen submarines was based at the military town of Fokino, about two hours from Vladivostok. Reportedly only a few submarines will be deployed to other locations, and the rest will be dismantled at the nearby Zvezda plant.[51]

Today, the principal Russian naval targets for U.S. strategic nuclear weapons are likely to be the SSBN basing areas of the Northern Fleet and the Pacific Fleet. Twelve SSBNs are deployed at two Northern Fleet bases and five SSBNs are at one Pacific Fleet base.

Northern Fleet

During the Cold War the Soviet Union created a vast military/nuclear complex on the Kola Peninsula (which is known by the Russians as the "land of the dammed") and along the adjacent White Sea.[52] The main strategic sites for the Northern Fleet are shown in Figure 4.33.

Most of the Soviet Navy's newest warships had home parts at Severomorsk and ten other deep harbors in this region. The Kola Inlet (Kol'skiy Zaliv) extends approximately 70 kilometers inland before becoming the Tuloma River. Along the shores of the Kola Inlet are the cities of Murmashi, Kola, Murmansk (the largest city north of the Arctic Circle), Severomorsk (headquarters of the Northern Fleet), Polyarnyy (a major base for Northern Fleet submarines and ships) and Skalistyy. In addition to the Murmansk-

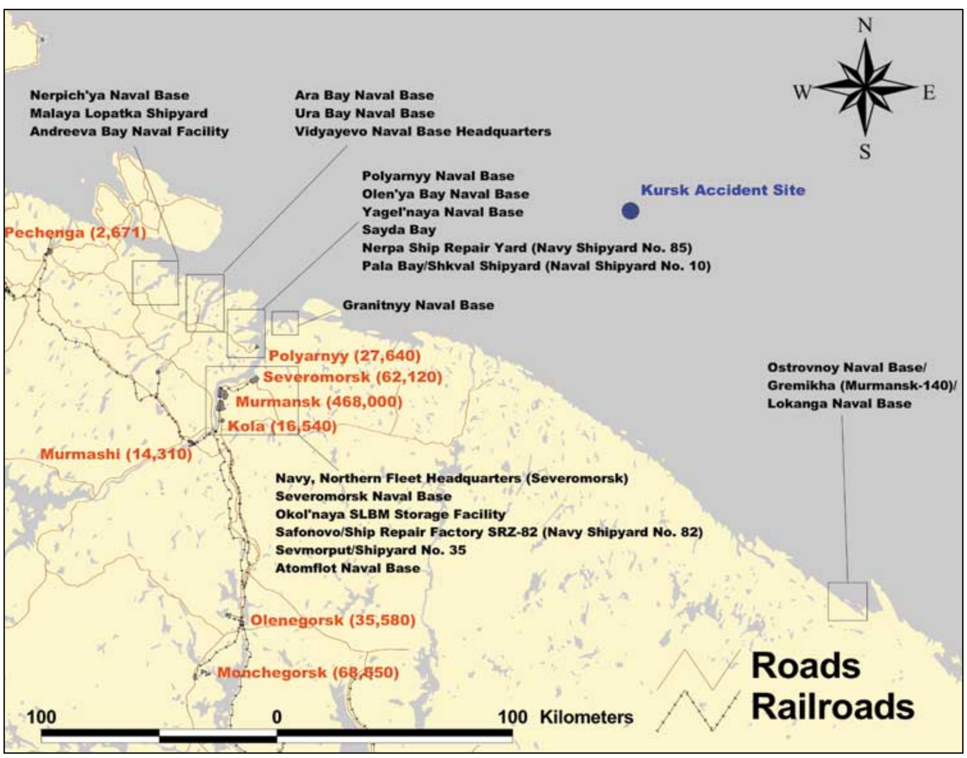


FIGURE 4.33
Main Sites of the Russian Northern Fleet
Population data from the 1989 Census is shown in red, and the approximate location of the *Kursk* submarine accident site is shown in blue.

Severomorsk-Polyarnyy complex, ships and submarines are based at the ports of Gremikha, which is approximately 200 km eastwards from the Kola Inlet, and the Litsa Guba/Bolshaya Litsa Complex, which has four bases—three on the eastern side of the fjord: a nuclear submarine maintenance area, a base for nuclear attack submarines and a base for Typhoon and other SSBNs—and another submarine maintenance facility on the western side, and westward in the port of Pechenga. There are reportedly several tunnel facilities (in Sayda Bay) for submarine repair and missile reloading.

Pacific Fleet

The main Russian Navy Pacific Fleet facilities in the Far East are shown in Figures 4.34 and 4.35. The two largest cities potentially affected by MAO-NF in the Russian Far East are Vladivostok and Petropavlovsk-Kamchatskiy. Vladivostok is a port city of 700,000 on the Sea of Japan at the eastern end of the Trans-Siberian Railway (a seven-day rail journey from Moscow) and about 70 kilometers from China. Vladivostok ceased to be a closed city in 1992. Approximately 35 kilometers east of Vladivostok is the large submarine disassembly plant Zvezda, and 40-60 kilometers southeast of Vladivostok are several main naval facilities, including Chazma Naval Yard and Abrek Bay Naval Headquarters. Approximately 2,300 kilometers northeast of Vladivostok, on Russia's Kamchatka Peninsula, lies the city of Petropavlovsk-Kamchatskiy (1989 population 268,700) and the Rybachiy Naval Base, home to the Pacific Fleet's remaining SSBNs (see Figure 4.35). Both the city and the naval base are situated along Avachinskaya Bay near the southern end of the Peninsula. Rybachiy Naval Base and the city of Petropavlovsk-Kamchatskiy are separated by about 20 kilometers.

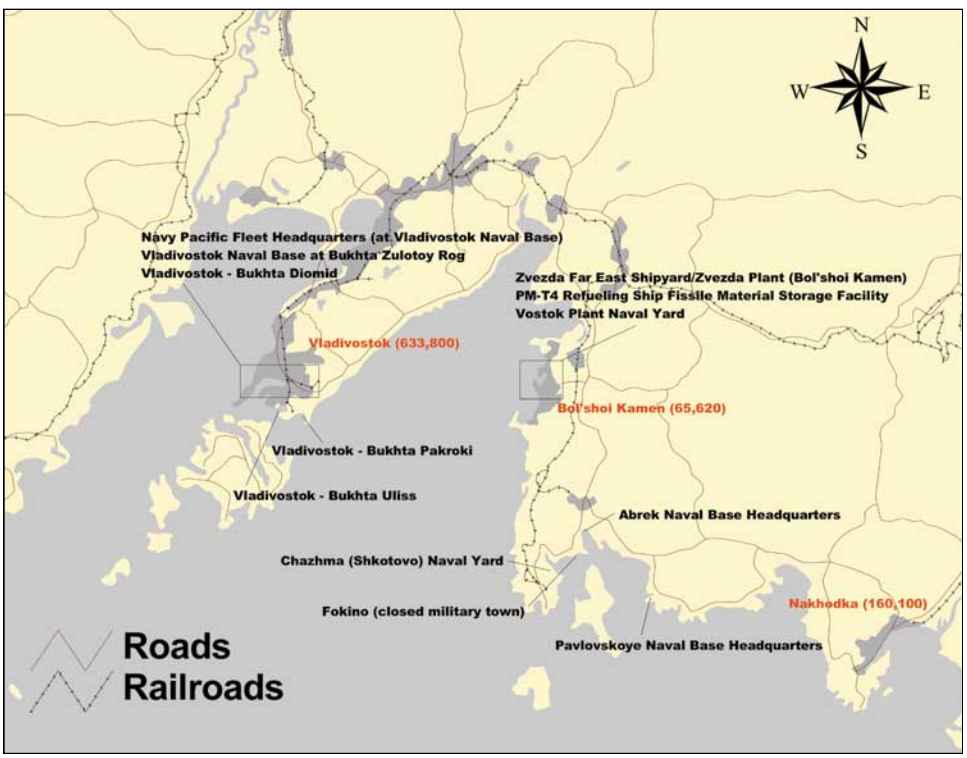
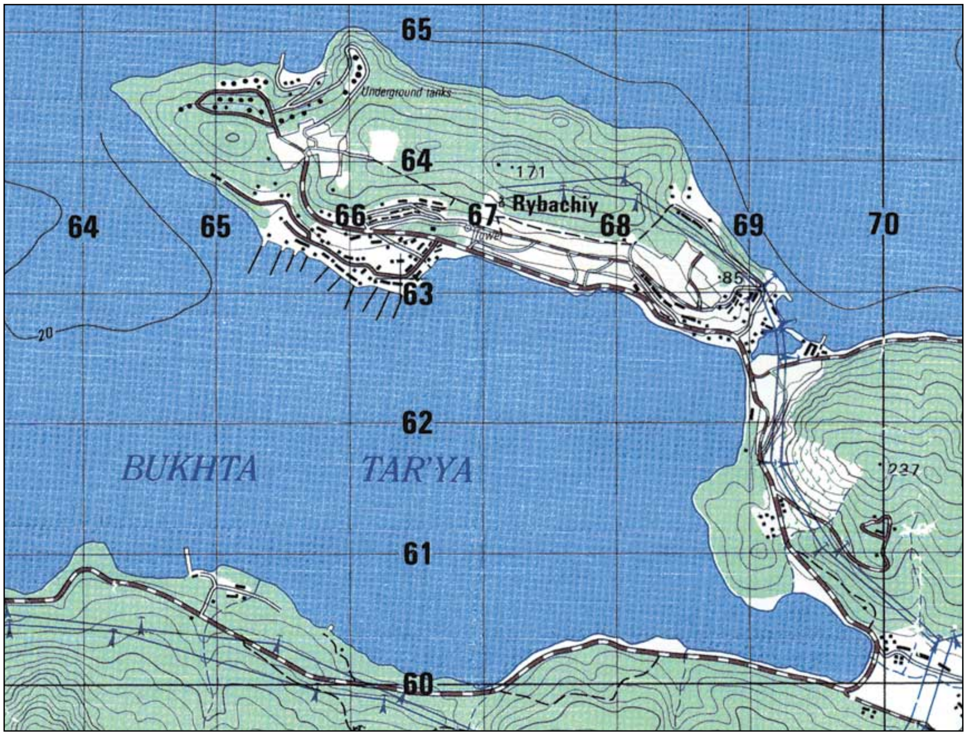


FIGURE 4.34
Main Sites of the Russian Pacific Fleet in Primorskiy Kray
These sites are located at and near the city of Vladivostok. Population data comes from the 1989 Soviet Census.

FIGURE 4.35
The Russian Naval Base of Rybachiy on the Kamchatka Peninsula
Near the city of Petropavlovsk-Kamchatskiy.



Warhead Requirements and Aimpoints

Since long-range Russian SSBN patrols are now infrequent, for MAO-NF we assume that many, most, or possibly all, of the moored submarines are at some stage of alert and are thus potential stationary firing platforms. We also explore the possibility that Russian SSBNs might disperse to other naval bases.

Vulnerability numbers for naval targets are provided in Table 4.7, showing three levels of damage (A, B and C) for three characteristics (seaworthiness, mobility and

FIGURE 4.36
Probability of Severe Damage to Surfaced Submarines, Aircraft Carriers and Destroyers for a W76 Ground Burst as a Function of Distance Between Ground Zero and Target
A CEP of 183 meters was used for these calculations.

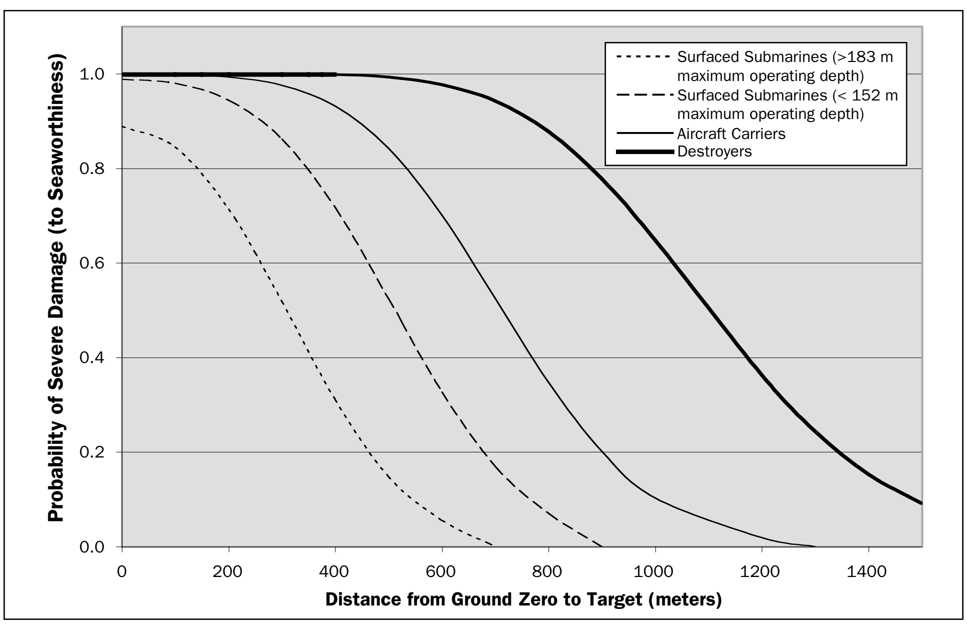


TABLE 4.7
Nuclear Weapons Vulnerability Data for Naval Targets
Naval shore structures and some associated objects, submarines and surface vessels. Types “A”, “B” and “C” damage to submarines and surface ships refer to successively more severe damage to seaworthiness, mobility and weapon delivery capabilities. Vulnerability numbers followed by an asterisk are for Equivalent Target Area Dimensions (Contact Burst) width/height. SS stands for single story, MS for multi-story, WF for wood framed, WB for masonry load-bearing wall, SF for steel-framed buildings with at least a 10-ton crane capacity, LSF for light-steel-framed buildings without cranes or with a 10-ton crane capacity, VLSF for very light steel-framed buildings, and RC for reinforced concrete building types. Source: *Physical Vulnerability Handbook—Nuclear Weapon* (U), pp. I-11, I-19 and I-20.

STRUCTURES AND OBJECTS (OTHER THAN SUBMARINES AND SURFACE SHIPS)

Target	Damage	VN
Naval Operating Base Administration Buildings (MS/SF or RC)	SDC	12P2
Naval Operating Base Administration Buildings (MS/WB)	SSD	10P0
Naval Operating Base Supply Buildings (MS/SF or RC)	SDC	12P2
Naval Operating Base Supply Buildings (SS/WB)	SSD	10P0
Naval Operating Base Supply Buildings (MS/WB)	SSD	10P0
Naval Operating Base Supply Buildings (SS/VLSF)	SSD	12Q7
Naval Operating Base Barracks (MS/WB)	SSD	10P0
Naval Operating Base Barracks (SS or MS/WF)	SSD	8P0
Naval Shipyard and Repair Base (Small Vessels and Submarines); Major Shops (Foundry, Machine, etc.); SS/SF	MSD	12Q7
Naval Shipyard and Repair Base (Small Vessels and Submarines); Major Shops (Foundry, Machine, etc.); SS/RC	MSD	12Q6
Naval Shipyard and Repair Base (Small Vessels and Submarines); Assembly Area (Locomotive and Crawler Cranes)	Overturning Cranes	15Q6
Naval Shipyard and Repair Base (Large Vessels); Shipways and Fitting-Out Areas	Overturning Light Portal and Tower Cranes	11Q7
Naval Shipyard and Repair Base (Large Vessels); Major Shops (Foundry, Machine, etc.); SS/SF	MSD	13Q7
Naval Shipyard and Repair Base (Large Vessels); Major Shops (Foundry, Machine, etc.); SS/RC	MSD	13Q6
Naval Shipyard and Repair Base (Large Vessels); Assembly Area (Locomotive and Crawler Cranes)	Overturning Cranes	15Q6
Naval Shipyard and Repair Base (Large Vessels); Shipways and Fitting-Out Areas	Overturning Portal and Tower Cranes	13Q8
Naval Shipyard and Repair Base (Large Vessels); Shipways and Fitting-Out Areas	Overturning Gantry Cranes	14Q9
Naval Shipyard and Repair Base (Large Vessels); Shipways and Fitting-Out Areas	Distortion of Runways of Overhead Cranes	15Q7
Naval Shipyard and Repair Base (Large Vessels); Shipways and Fitting-Out Areas	Overturning Hammerhead Cranes	17Q9
Graving Docks and Dry Docks	Sidewall Collapsed and Dock Obstructed or Gate Ruptured	52P0/ 31P0*
Graving Docks and Dry Docks	Sidewall cracked and Lock Obstructed by Crater Lip or Gate Ruptured	40P0/ 31P0*
Steel Floating Dry Docks	Deformation of sidewalls and overturning of cranes	16P0
Steel Floating Dry Docks	Overturning of cranes on sidewalls	13Q8
Wooden Wharves and Piers	Unseating of Timber Stringers and Floor System	17P0
Concrete or Stone Wharves, Piers and Quays	Destruction	46P0
POL Storage		
Ammunition Storage		

SUBMARINES AND SURFACE SHIPS

	Seaworthiness			Mobility			Weapons		
	A	B	C	A	B	C	A	B	C
Surfaced Submarines (>183 meters maximum operating depth)	30P0	29P0	27P0	—	—	28P0	28P0	26P0	23P0
Surfaced Submarines (<152 meters maximum operating depth)	24P0	22P0	21P0	—	—	—	—	—	—
Aircraft Carriers, Cruisers, Transports, LST's, Landing Craft and Landing Vehicles	20P0	18P0	15P0	15P0	14P0	13P0	13P0	11P0	7P0
Destroyers	15P0	14P0	13P0	13P0	12P0	11P0	13P0	11P0	7P0

Target	Damage	VN
Merchant Ships	Unseaworthy; in danger of sinking, capsizing, or breaking up	20P0
Merchant Ships	About one-half loss of seaworthiness	18P0

weapons delivery) for submarines and ships. A description of the damage levels is provided in Table 4.8. Figure 4.36 shows the probability of achieving severe damage to seaworthiness (and thus also severe damage to weapons systems) for various vessel types as a function of distance between W76 ground zero and target. The damage radius for severe damage to surfaced submarines (capable of operating deeper than 183 meters) is found to decrease rapidly to zero for heights of burst of only several hundred meters. Therefore we select W76 ground bursts for all Russian naval targets.

In our MAO-NF, we examine two levels of attack against Northern Fleet targets and three levels of attack against Pacific Fleet Targets. We limit the first level of attack against the Northern Fleet to the pier areas of the two Russian naval bases where Typhoons, Delta III, and Delta IV SSBNs are moored. We use a total of 18 W76 warheads to cause severe damage to the SSBNs and the pier areas. In the second level of attack, all of the other Northern Fleet's naval bases are also attacked using an additional 74 warheads, for a total of 92 W76 warheads for the second level of attack. Table 4.9 provides summary information on the targets chosen for these two Northern Fleet attack scenarios in our MAO-NF.

TABLE 4.8
Definitions of Damage Levels for Naval Targets
Description of the three levels of damage to ship and submarine seaworthiness, mobility and weapons delivery. Source: *Physical Vulnerability Handbook—Nuclear Weapon* (U), p. I-20.

Impairment Type	Description
Seaworthiness, Type A	For ships: In danger of sinking, capsizing, or breaking up because of widespread, uncontrollable flooding or loss of girder strength. Danger is present even in normal weather, but there is some chance of saving the ship. For submarines: In danger of settling to the bottom because of damage to its structure of buoyancy-control gear.
Seaworthiness, Type B	For ships: About half-loss of seaworthiness, evidenced by appreciable plastic deformation of structure, possibly leading to rupture. This includes loss of girder strength or of topside structure to an extent that the ship is in danger of being swamped or being broken up in stormy weather. Any flooding is confined by compartmentation or by a side-protection system. For submarines: Loss of ability to submerge in a controlled manner because of damage to structure or buoyancy-control gear.
Seaworthiness, Type C	For ships: Slight plastic deformation of structure, which may cause minor leakage. Hogging or sagging, or topside structural damage may occur, but not enough to endanger the ship, even in stormy weather. For submarines: Slight reduction of maximum safe diving depth but can submerge in a controlled manner.
Mobility, Type A	For ships: Can at best just barely maintain steerageway in a desired direction, because of damage to main propulsion equipment, auxiliary machinery, and control gear, or because of personnel casualties. For submarines: Seaworthiness impairment controls.
Mobility, Type B	For ships: About half loss of mobility. Can maintain steerageway in a desired direction without difficulty, but cannot achieve speeds appreciably greater than half top speed, and/or cannot maneuver normally within its remaining speed range, because of damage to equipment and/or control gear, or because of personnel casualties. For submarines: Seaworthiness impairment controls.
Mobility, Type C	For ships or submarines: Slight loss of ability to achieve top speed and/or to maneuver normally, because of equipment damage or personnel casualties.
Weapon Delivery, Type A	Weapons can be released, but it is almost impossible to deliver them effectively because the target-acquisition and communication equipments are inoperative, either from damage to equipment or topside structure, or because of personnel casualties.
Weapon Delivery, Type B	About half-loss in ability to deliver weapons effectively, because of damage to equipment or topside structure, or because of personnel casualties.
Weapon Delivery, Type C	Slight reduction in weapon-delivery efficiency due to equipment or topside structural damage, or to personnel casualties.

TABLE 4.9
Northern Fleet Aimpoints for Two Levels of Attack.

Level of Attack	Target Description	Number of Aimpoints
1	**Nerpich'ya Naval Base:** (in Zapadnaya Litsa Bay approximately 50 km west of the mouth of the Kola Inlet); 3 Typhoon SSBNs (60 SLBMs); piers potentially distributed over 2,700 meters of coastline	8 (300 meters between aimpoints)
1	**Yagel'Naya Naval Base:** (in Sayda Bay near the town of Skalistyy at the mouth of the Kola Inlet); 2 Delta III (32 SLBMs) and 7 Delta IV SSBNs (112 SLBMs); piers potentially distributed over 3,500 meters of coastline	10 (300 meters between aimpoints)
Total Aimpoints for Attack Level 1		***18***
2	**Murmansk-Pinagoriy Area and Sevmorput Shipyard:** (central and northern portions of Murmansk); SSBN repair yard (refueling prior to 1992)	0 (withhold on cities under MAO-NF)
2	**Safonovo Ship Repair Factory SRZ-82:** (10 km northeast of Murmansk) nuclear ship and sub repair	1
2	**Severomorsk Naval Base:** (15 km northeast of Murmansk) 30 surface ships, including heavy aircraft carrier *Admiral Kuznetsov*, heavy nuclear-powered missile-armed cruisers of the Admiral Ushakov class (Krov) and the *Marshal Ustinov* missile-armed cruiser of the Slava class; piers potentially distributed over 10,000 meters of coastline	11 (750 m separation between aimpoints)
2	**Okol'naya SLBM Storage Facility:** (1 km east of Severomorsk)	1
2	**Polyarnyy Naval Base:** (26 km northeast of Murmansk) minor surface combatants; diesel submarines; a naval station of the Kola flotilla (surface ships and submarines of offshore defense brigades); piers potentially distributed over 1,000 meters of coastline	4 (300 m between aimpoints)[53]
2	**Pala Bay/Shkval Shipyard:** (24 km northeast of Murmansk) auxiliaries; piers potentially distributed over 1,500 meters of coastline	2 (750 m between aimpoints)
2	**Olen'ya Bay:** (25 km northeast of Murmansk) former SSBN base; surface ships and submarines of offshore defense brigades; piers potentially distributed over 1,700 meters of coastline	5 (300 m between aimpoints)
2	**Nerpa Ship Repair Yard and Kut Bay Docking Area:** (24 km northeast of Murmansk) piers potentially distributed over 3,000 meters of coastline	5 (750 m between aimpoints)
2	**Sayda Bay:** (western end) piers	2
2	**Granityy Naval Base:** (13.5 km east of the mouth of the Kola Inlet) torpedo and missile boats	2
2	**Teriberka:** (piers, 65 km southeast of the mouth of the Kola Inlet) patrol ships	1
2	**Ostrovnoy Naval Base:** (located at the city of Gremikha, 280 km southeast of the mouth of the Kola Inlet); piers potentially distributed over 3,000 meters of coastline	4 (750 m between aimpoints)
2	**Port Vladimir:** (19 km west of the mouth of the Kola Inlet) minor surface combatants (minesweepers, etc.)	1
2	**Ura Bay Naval Base and adjacent Piers:** (35 km northwest of Murmansk) piers potentially distributed over 8,000 meters of coastline	10
2	**Ara Bay:** (40 km northwest of Murmansk) piers potentially distributed over 3,000 meters of coastline	8 (300 m between aimpoints)
2	**Bolshaya Lopatka Naval Base:** (in Zapadnaya Litsa Bay approximately 50 km west of the mouth of the Kola Inlet) piers potentially distributed over 2,000 meters of coastline	6 (300 m between aimpoints)
2	**Malaya Lopatka:** (in Zapadnaya Litsa Bay approximately 50 km west of the mouth of the Kola Inlet)	2
2	**Andreeva Bay:** (in Zapadnaya Litsa Bay approximately 50 km west of the mouth of the Kola Inlet)	1
2	**Pechenga:** (96 km northeast of Murmanks) conventional submarines and escort ships	2 (the north end and mid-way up the fjord)
2	**Severodvinsk:** (along the White Sea near Arkhangel) workshops for construction and modernization of submarines; base for minor surface ships; SLBM loading facility	5 (spaced mid-way along the length of the Severodvinsk inlet)
2	**Belomorsk:** (along the White Sea 300 km west of Arkhangel) a naval station of the Kola flotilla; surface ships and submarines	1
Total Aimpoints for Attack Level 2		***92***

We take a similar approach in selecting Pacific Fleet targets. However, since three sites are in or near populated areas, these are not included in the first two levels of attack. We limit the first level of attack to the pier area of the Rybachiy Naval Base where five Delta III SSBNs are moored. Twelve W76 warheads are used to cause severe damage to the SSBNs and the pier areas. In the second level of attack, all but three of the other Pacific Fleet's naval bases are targeted as well with an additional 18 warheads, bringing the total to 23 W76 warheads. In the third level of attack, three additional sites in the vicinity of populous areas are attacked with 22 warheads, bringing the total to 45 W76 warheads for the third attack level. Table 4.10 provides a summary of the Pacific Fleet targeted in MAO-NF. In all cases, we select surface bursts with the objective of causing severe damage to ships or submarines moored at pier areas.

Casualties and Sensitivity Analysis

The first level of attack against Russian naval sites in NRDC's MAO-NF—targeting only the pier areas where SSBNs are moored—requires a total of 30 W76 warheads. In our judgment, this is likely to be the minimum level of attack against this component of Russian strategic nuclear forces in the actual U.S. SIOP. Figures 4.37 and 4.38 contrast the fallout patterns calculated for NRDC's first and second levels of attack against Northern Fleet targets. Even in the first level of attack against the Russian Northern Fleet, almost one megaton of nuclear explosive yield is detonated (as surface bursts) at each of the two SSBN bases, and consequently the range of lethal fallout extends some 100 kilometers from the ground zeroes for an unsheltered population. This is farther than distances between Nerpich'ya Naval Base or Yagel'naya Naval Base and the city of Murmansk.

TABLE 4.10
Pacific Fleet Aimpoints for Three Levels of Attack

Level of Attack	Target Description	Number of Aimpoints
1	Rybachiy Naval Base	12
Total Aimpoints for Attack Level 1		***12***
2	Pavlovskoye Naval Base	3
2	Abrek Bay	3
2	Navy Site 34 Fresh Fuel Storage Facility	1
2	Zavety Il'icha Naval Base	1
2	Sovetskaya Gavan Naval Station	1
2	Chazma Naval Yard	1
2	Ol'ga Naval Base	1
Total Aimpoints for Attack Level 2 (including attack level 1 targets)		***23***
3	Bolshoi Kamen	3
3	Korsakov Naval Base	1
3	Vladivostok-area Naval sites	18
Total Aimpoints for Attack Level 3 (including attack level 1 and 2 targets)		***45***

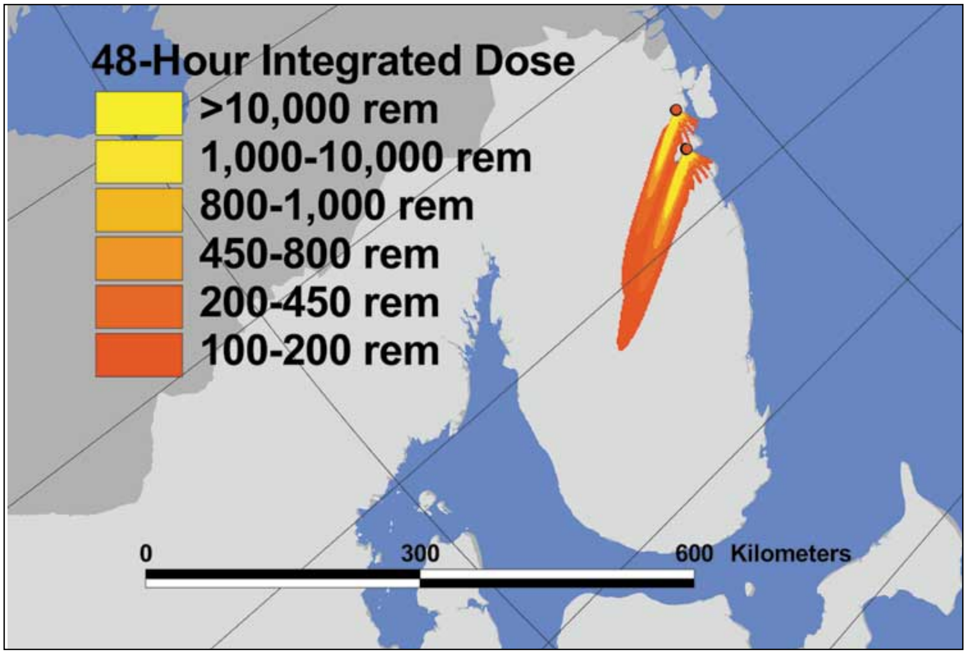


FIGURE 4.37
Fallout Patterns over the Kola Peninsula for the First Level of Attack
Against Russian SSBNs at Nerpich'ya and Yagel'Naya Naval Bases. This calculation uses the most probable wind patterns for the month of December, and assumes the 18 attacking W76 warheads have a fission fraction of 80 percent and the population is unsheltered. Principally as a result of fallout, a total of 307,000 casualties are calculated to occur, including 259,000 fatalities.

Figures 4.39 and 4.40 show the summary casualty data for the first and second levels of attack, respectively, against Northern Fleet targets as a function of warhead fission fraction and population sheltering. Figures 4.41 and 4.42 plot casualties and fatalities by month for the first and second levels of attack against Northern Fleet targets. Seasonal changes in wind speed and direction cause the monthly variation.

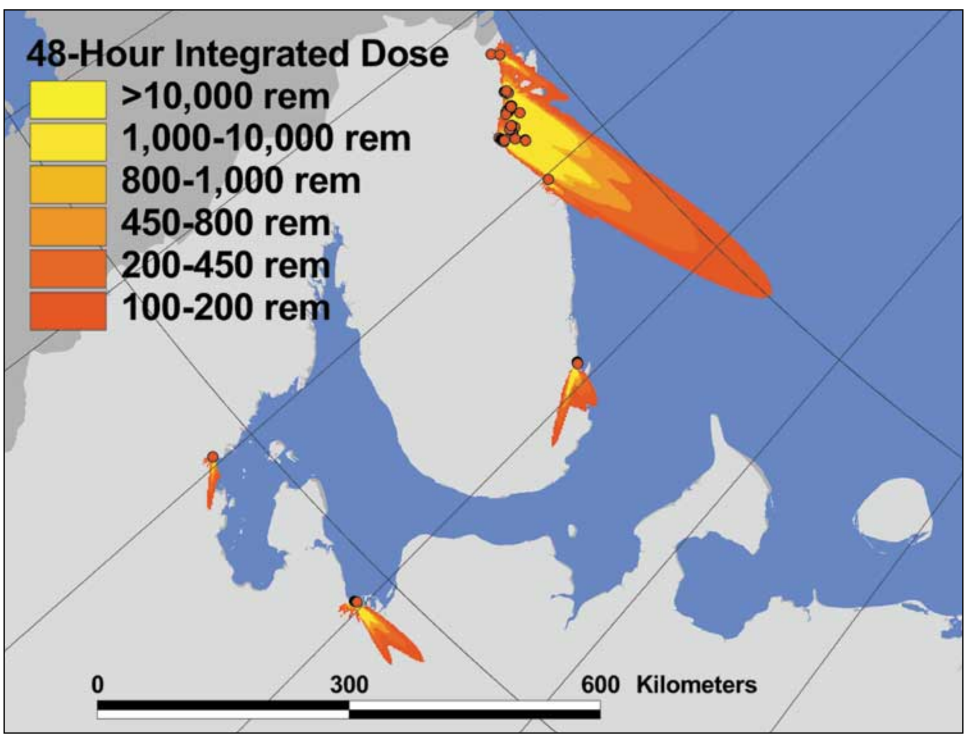
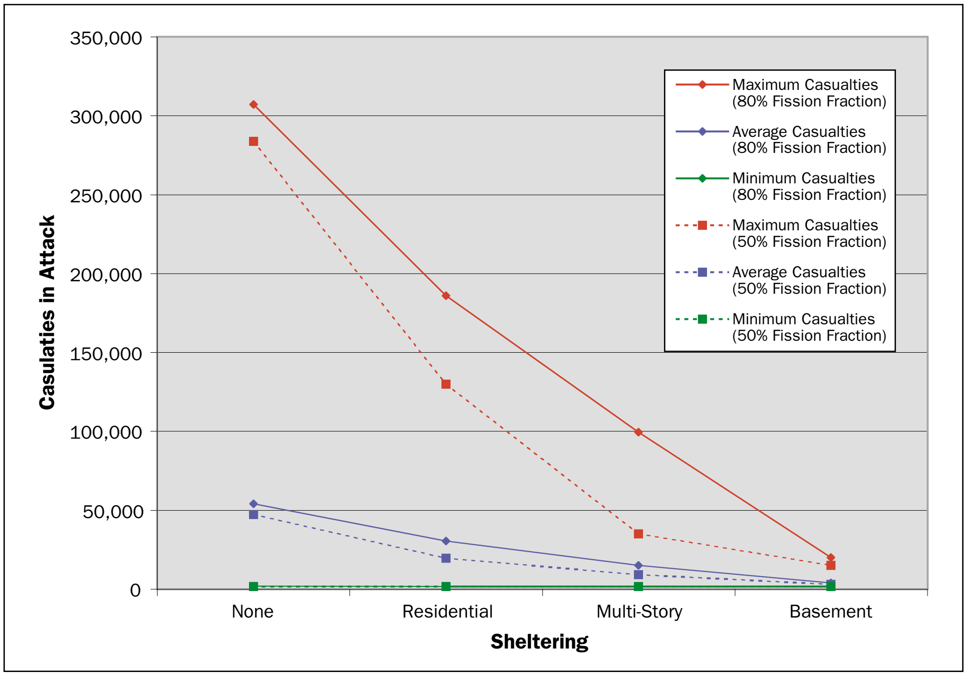


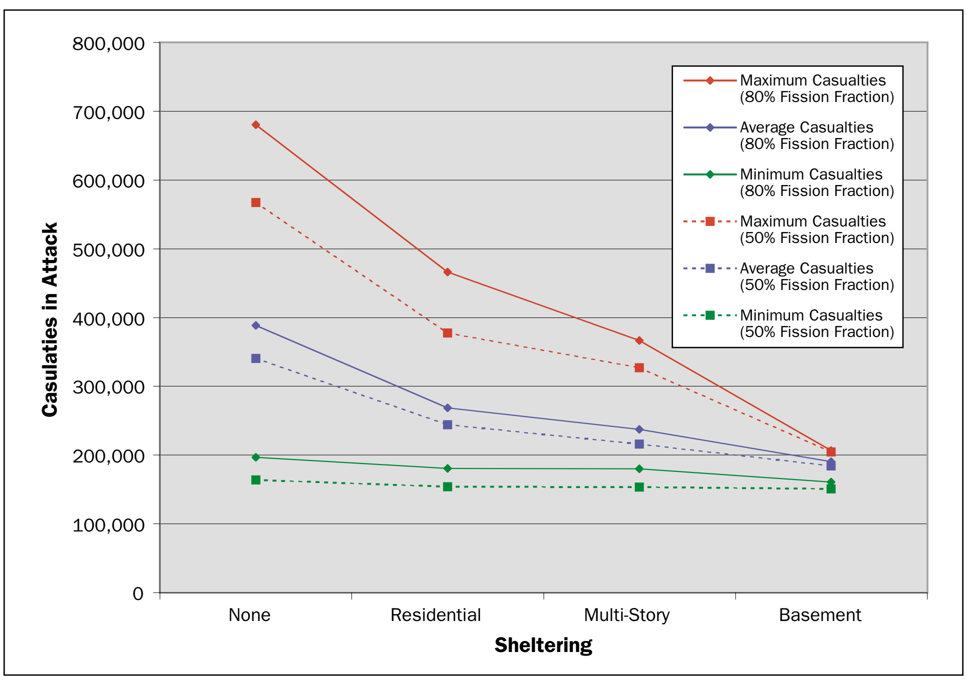
FIGURE 4.38
Fallout Patterns over the Kola Peninsula for the Second Level of Attack
Against Russian SSBNs at Nerpich'ya and Yagel'Naya Naval Bases and 18 other Northern Fleet facilities. This calculation uses the most probable wind patterns for the month of August, and assumes that the 92 attacking W76 warheads have a fission fraction of 80 percent and the population is unsheltered. A total of 503,000 casualties are calculated to occur, including 412,000 fatalities.

FIGURE 4.39
Summary Casualty Data for the First Level of Attack on the Russian Northern Fleet



These calculations demonstrate that for most months of the year, the fallout patterns from the first level of attack would occur over sparsely populated regions. For certain months, notably January, February, and November, fallout would descend over Murmansk and its vicinity, causing the number of civilian casualties to approach 200,000. For the second level of attack against the Russian Northern Fleet—in which an additional 7.4 megatons of nuclear explosive yield was detonated at

FIGURE 4.40
Summary Casualty Data for the Second Level of Attack on the Russian Northern Fleet



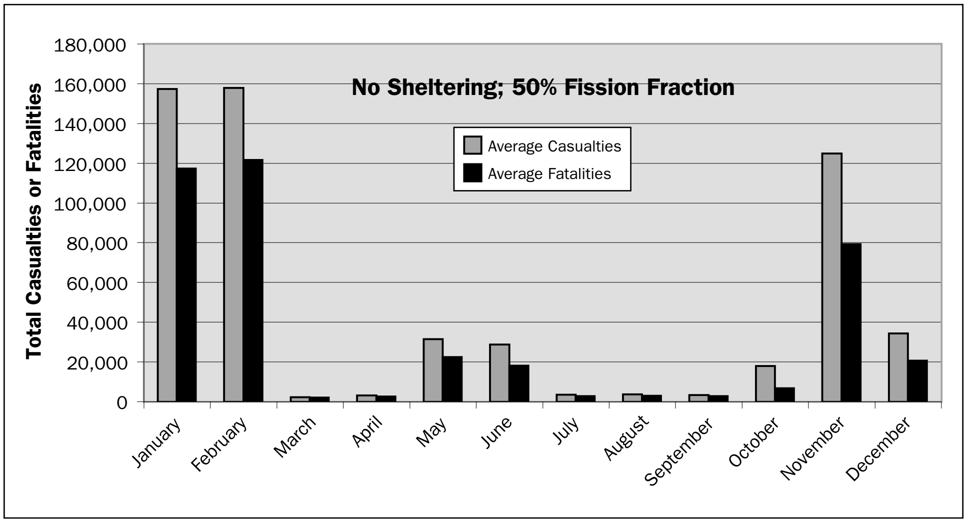


FIGURE 4.41
Casualties and Fatalities as a Function of the Month of the Year for the First Level of Attack against the Russian Northern Fleet
A fission fraction of 50 percent and no sheltering is assumed for this calculation.

18 other naval sites—the range of casualties is computed to be 153,000–466,000, including from 151,000 to 340,000 fatalities. It is notable that the maximum number of civilians threatened by the first level of attack against the Russian Northern Fleet is within the range of the second level of attack, despite the greater number of warheads used and sites attacked.

Figures 4.43 through 4.45 display fallout patterns from the first, second and third levels of attack against the Russian Pacific Fleet. In the first level of attack, in which more than one megaton of nuclear explosive yield is detonated (as surface bursts) at the Rybachiy Naval Base, the most probable wind patterns for all months of the year blow the fallout over the ocean. Figures 4.46 and 4.47 show the summary casualty data for the second and third levels of attack, respectively, against Russian Pacific Fleet targets as a function of warhead fission fraction and population sheltering. Figures 4.48 and 4.49 plot casualties and fatalities by month for the second and third levels of attack.

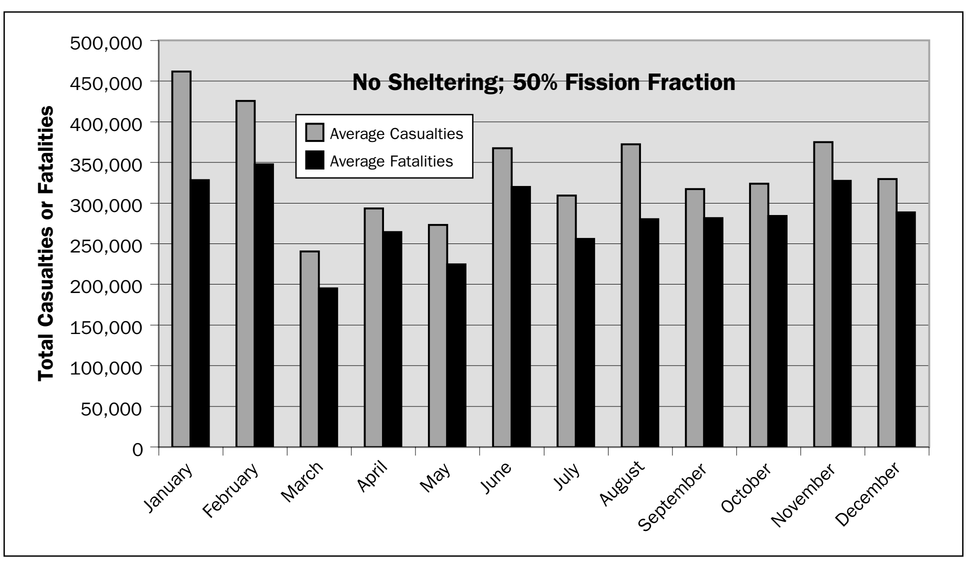
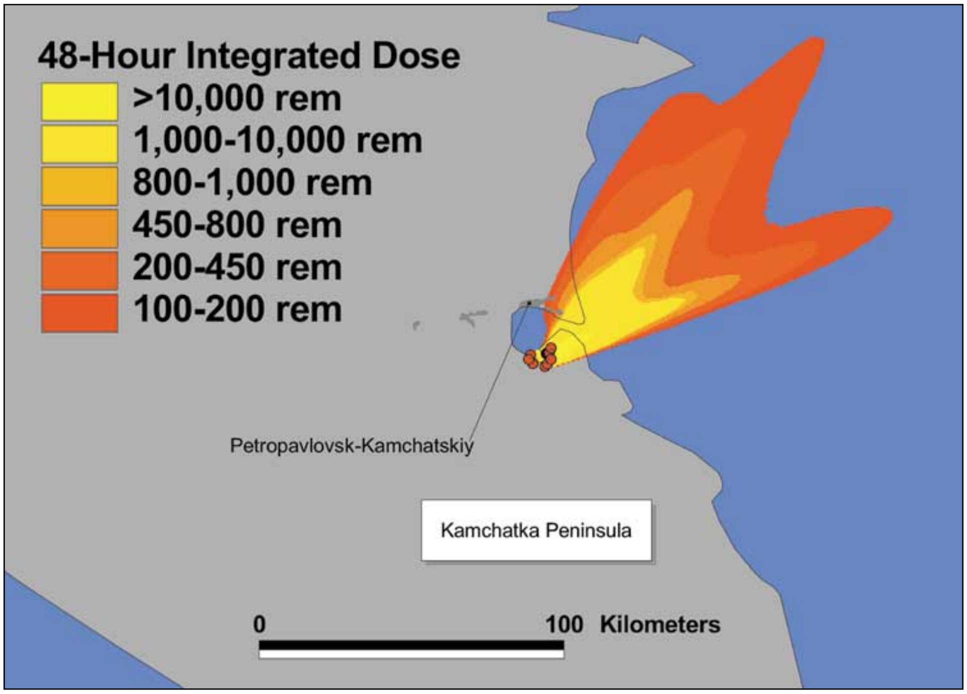


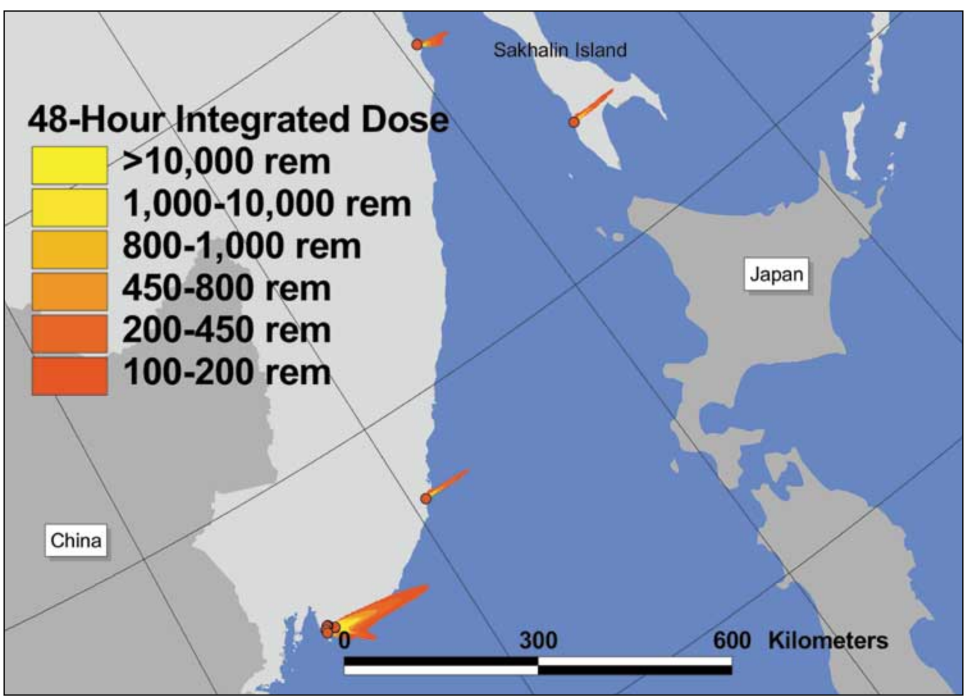
FIGURE 4.42
Casualties and Fatalities as a Function of the Month of the Year for the Second Level of Attack against the Russian Northern Fleet
A fission fraction of 50 percent and no sheltering is assumed for this calculation.

FIGURE 4.43
Fallout Patterns from the Attack on the Rybachiy Naval Base
With twelve W76 ground bursts. The parameters of the calculation are: the most probable winds for the month of January, a warhead fission fraction of 80 percent and an unsheltered population. Because the fallout occurs mostly over the ocean, the number of fatalities calculated is less than one percent of the population of nearby Petropavlovsk-Kamchatskiy.



For the second level of attack against the Russian Pacific Fleet—in which a total of 2.3 megatons of nuclear explosive yield is detonated at eight naval sites (including Rybachiy)—casualties would range from 8,000–44,000, including from 8,000 to 20,000 fatalities. As noted above, this represents a small percentage of the population in the vicinity of these sites. We compute that population centers would lay largely outside the fallout zones because of the prevailing winds. When targets in or very close to

FIGURE 4.44
Fallout Patterns from the Second Level of Attack Against the Russian Pacific Fleet
Using a total of 23 W76 warheads. The parameters of the calculation are: the most probable winds for the month of April, a fission fraction of 80 percent, and an unsheltered population. A total of 149,000 casualties are calculated to occur, including 114,000 fatalities.



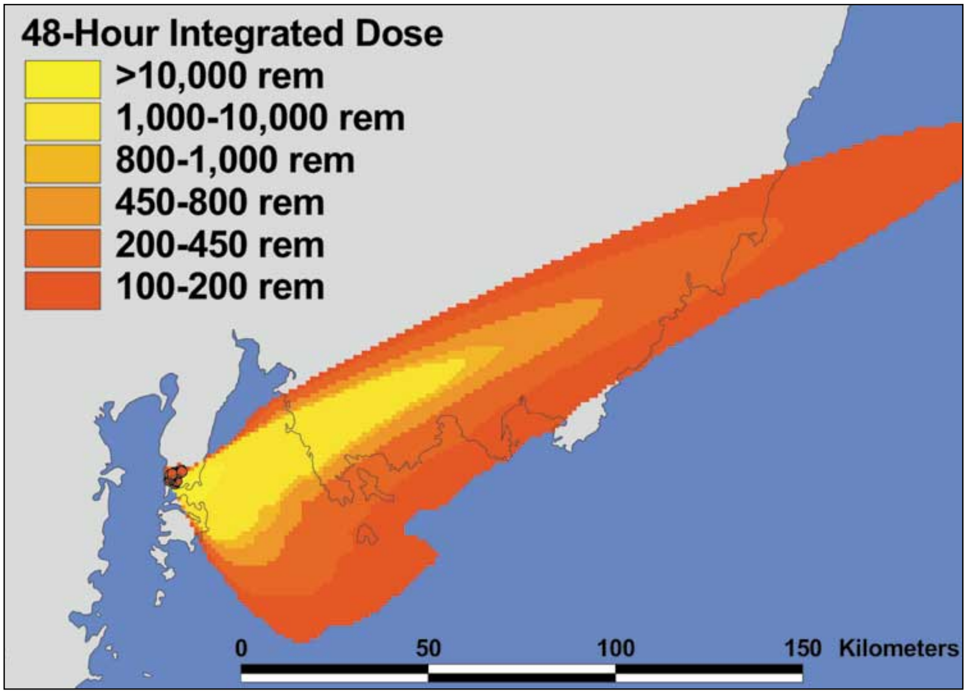


FIGURE 4.45
An Attack on the Vladivostok Harbor, Part of the Third Level of Attack Against the Russian Pacific Fleet
This calculation assumes winds typical of the month of January, fission fraction of 80 percent, and no sheltering. The total casualties calculated for the attack by 18 W76 warheads on the Vladivostok port area are 236,000 and the total calculated fatalities are 158,000.

population centers are included in a nuclear attack, as is the case for MAO-NF's level three targeting against the Russian Pacific Fleet, the computed casualties and fatalities become much less sensitive to the wind parameters. For the third level of targeting against the Russian Pacific Fleet, which includes Vladivostok harbor, the Zvezda plant and Korsakov Naval Base on Sakhalin Island, casualties are computed to approach one-half million.

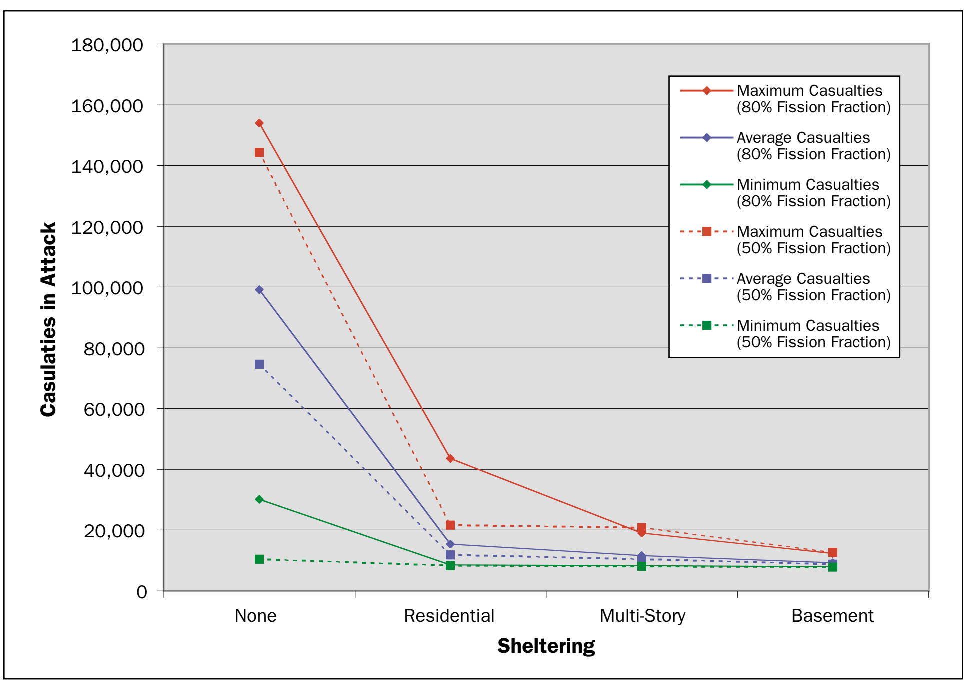


FIGURE 4.46
Summary Casualty Data for the Second Level of Attack on the Russian Pacific Fleet

FIGURE 4.47
Summary Casualty Data for the Third Level of Attack on the Russian Pacific Fleet

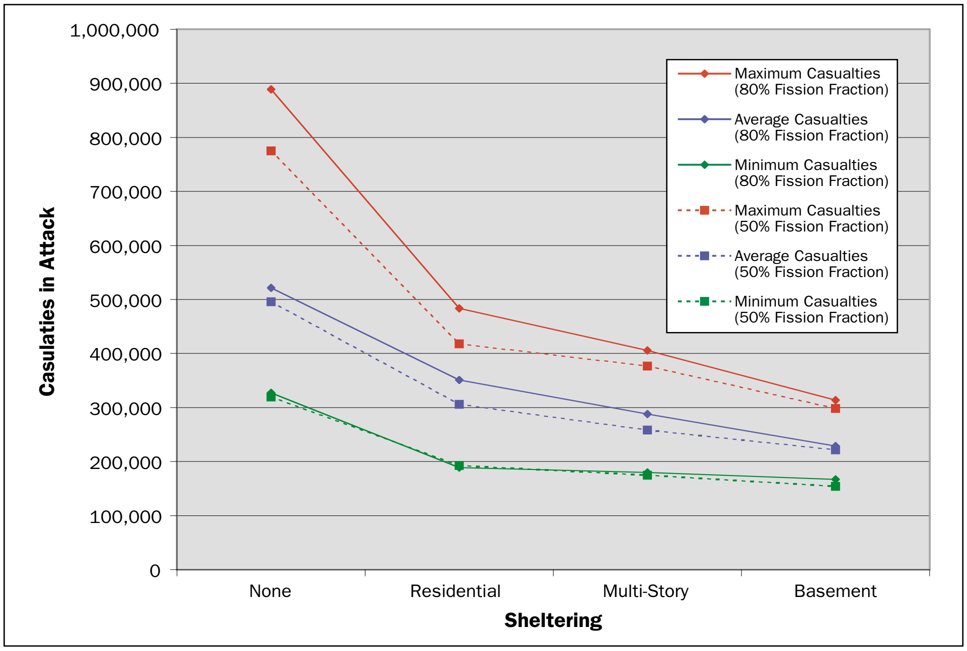


FIGURE 4.48
Monthly Variation in Casualties and Fatalities for the Second Level of Attack Against the Russian Pacific Fleet

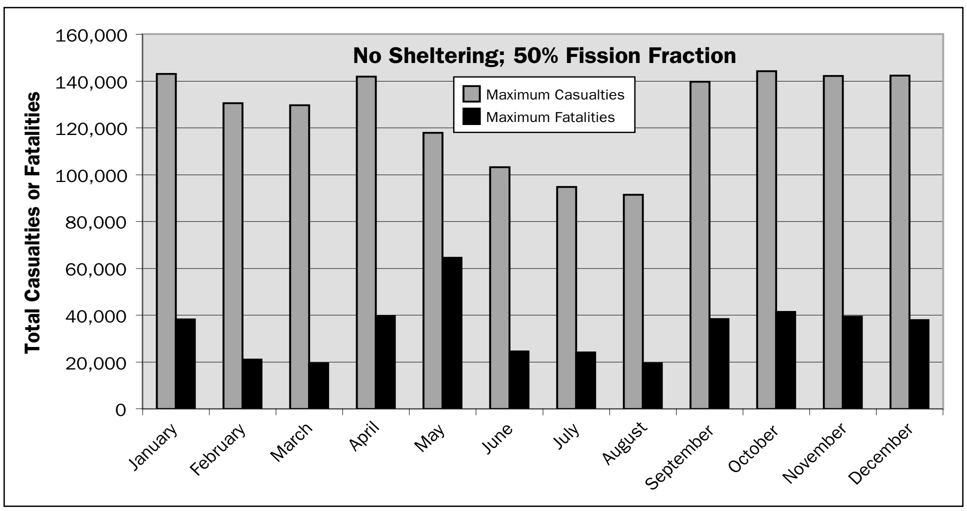
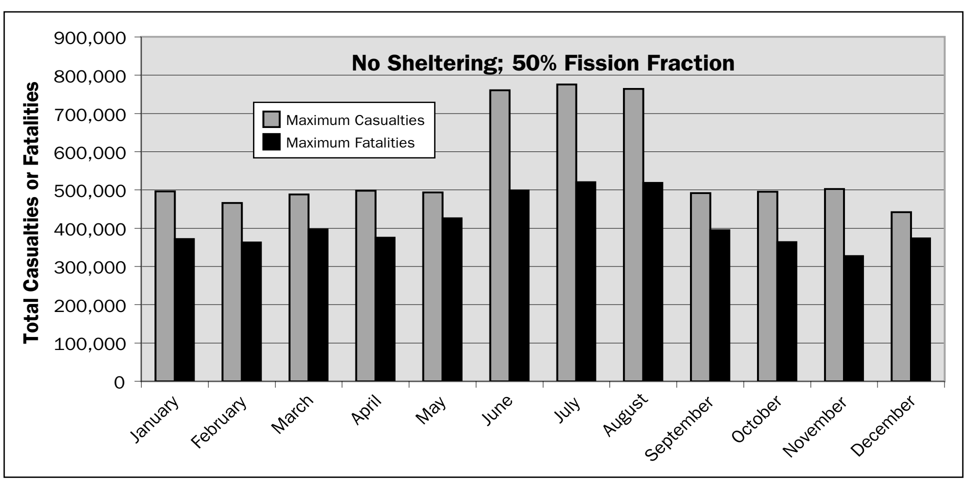


FIGURE 4.49
Monthly Variation in Casualties and Fatalities for the Third Level of Attack Against the Russian Pacific Fleet



LONG-RANGE BOMBER BASES AND FACILITIES

Description of Targets

With the breakup of the Soviet Union, Russian Long-Range Aviation lost key air bases in Estonia at Pyarnu and Tartu; in Ukraine at Uzin and Priluki; and in Kazakhstan at Semipalatinsk, and lost custody of most of its Tu-160 strategic bombers to Ukraine for several years. Long Range Aviation (in Russian *Dalnaiaya Aviatsiya*—DA) was reorganized on May 1, 1998 into the 37th Air Army, with two of its divisions—the 22nd Heavy Bomber Division based at Engels and the 73rd Heavy Bomber Division at Ukrainka—operating long-range bombers.[54] The 182nd Guard Aviation Wing of Tu-95MS heavy bombers, which had been based at Mozdok Air Base since 1962, was disbanded in April 1998, and its 35 bombers were transferred to Engels Air Base.[55]

In the START I MOU dated 31 July, 2000, Russia declared a total of 81 deployed heavy bombers (66 Bears and 15 Blackjack bombers) and 11 test heavy bombers (six Bears and five Blackjacks). Ukrainka Air Base had 21 Bear H16 and 27 Bear H6 bombers and Engels Air Base had 13 Bear H16, 5 Bear H6 and all 15 Blackjack bombers. Figure 4.50 shows a Corona satellite image of Ukrainka Air Base taken on December 6, 1969. Figure 4.51 is a map showing Engels Air Base. The 11 test heavy bombers were at the Zhukovskiy Heavy Bomber Test Flight Center at Ramenskoye Airfield. According to Russian Air Force Major General Dmitry Morozov, 79 percent of long-range aircraft are serviceable.[56]

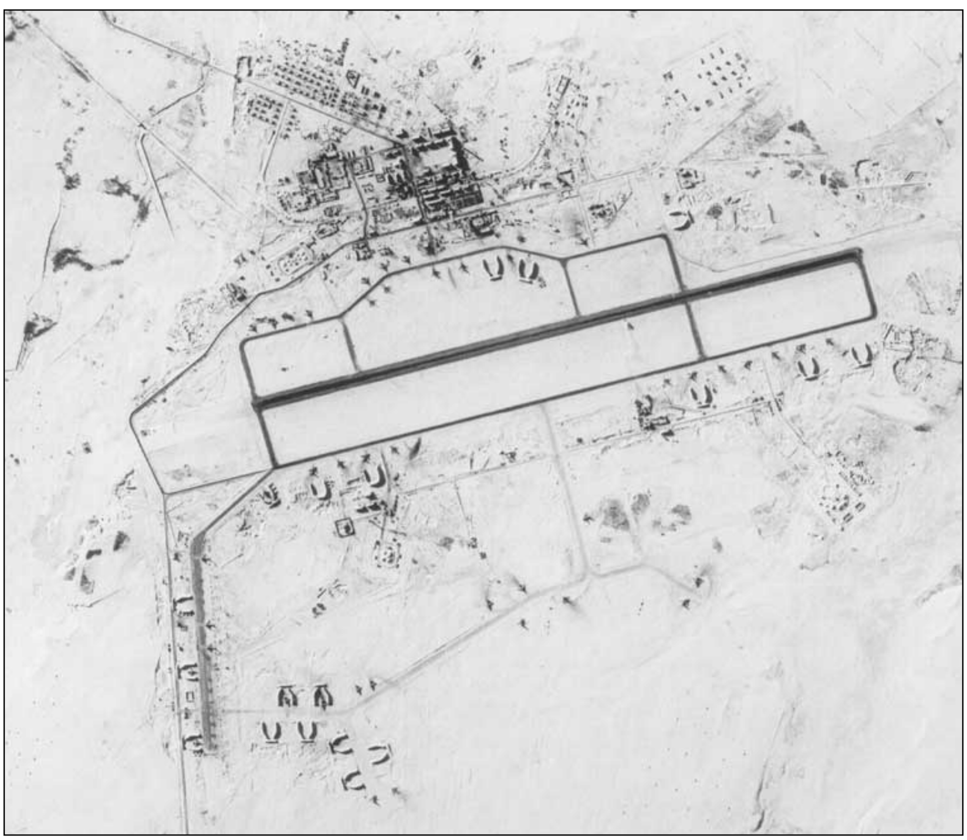


FIGURE 4.50
Corona Satellite Image of Ukrainka Air Base
Taken on December 6, 1969 during mission 1108-1. The Ukrainka Air Base is located in the Russian Far East at 51°10’ N, 128°26’ E, approximately 1,500 km due north of Seoul, South Korea. Source: Joshua Handler, Princeton University.

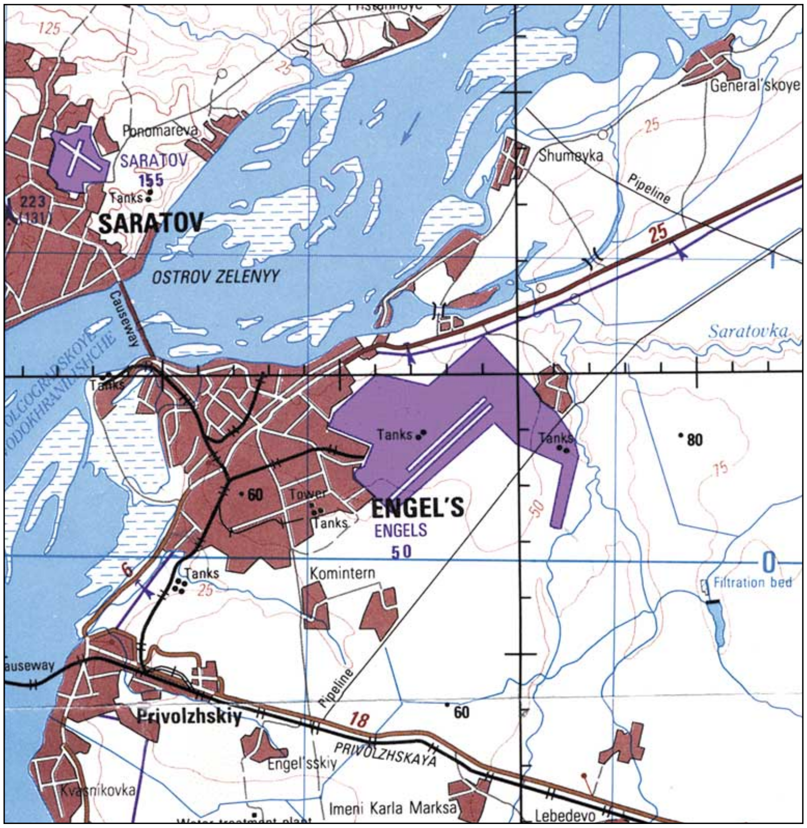


FIGURE 4.51
Engels Air Base, near the City of Saratov
(Population in the 1989 Soviet Census: 904,600). The air base is located at 51°28' N, 46° 11' E, approximately 750 kilometers from Moscow and adjacent to the Tatischevo missile field. Source: U.S. JOG NM 38-3, Series 1501, Edition 2, "Compiled in 1982."

Russia did not declare any new heavy bombers at the Aircraft Production Combines at Kazan' and Kuybyshev. Two Bear G bombers, described as "heavy bombers equipped for nuclear armaments [gravity bombs] other than long-range nuclear ALCMs," were declared to be at Ryazan Air Base, and at the strategic bomber elimination facility at Engels Air Base. The Russian Air Army training center and the major repair plant for bomber aircraft are located at Dyagilevo, near Ryazan.

During the week of September 17, 1999, the Russian Air Force and Navy conducted command-staff exercises in the Far East involving three Tu-95MS aircraft of the 73rd Heavy Bomber Division, based at the Ukrainka airfield. The strategic bombers forward-deployed to Anadyr Air Base in the Chukotskiy Autonomous District (see Figure 4.52 for a map of the base). In late November 2000, Russia moved several Bear bombers to Anadyr, Tiksi, and Vorkuta Air Bases. The threat to the United States posed by Russian bombers lies in the AS-15 Kent air-launched cruise missiles that they carry. (It is generally understood that today the chance of Russian bombers penetrating U.S. air space to drop gravity bombs is near zero.) The AS-15 has a range of 3,520 kilometers.

Warhead Requirements and Aimpoints

The MAO-NF focuses on the following strategic aviation targets: the main air bases at Engels and Ukrainka and the forward air bases where bombers might be dispersed, refueled, or armed. We examine two levels of attack against Russian strategic aviation assets. The first involves targeting the two strategic air bases, Engels and Ukrainka, the training base at Ryazan', the Zhukovskiy Heavy Bomber Flight Test Center, the Kuybyshev and Kazan' heavy-bomber production facilities, and selected forward air bases. The second level of attack adds additional air bases to the target list that could be used for dispersing of strategic bombers, refueling tankers or establishing air bases for potential Russian fighter escorts. Table 4.11 provides a list of all air bases for the two levels of attack. A total of 19 W76 warheads are used in the first level of attack against Russian strategic aviation targets, and an additional 54 W76 warheads are used in the second level of attack.

The objective of the MAO-NF nuclear attack is to destroy strategic bombers and other aircraft on the ground, crater airfield runways, and damage other

FIGURE 4.52
Anadyr Air Base
Located in the Russian Far East region of Chuckchi at 54°48' N, 177°34' E, approximately 800 kilometers from the Alaskan mainland. Source: U.S. JOG NQ 59,60-16, Series 1501, Edition 1, "Compiled April 1969 from best available sources."

long-range aviation assets, such as POL storage and aircraft repair and production facilities. Using the PV system, we assess the vulnerability of Soviet-built aircraft and associated aviation targets to blast effects (see Table 4.12).[57] Of the three types of aircraft, helicopters are the most vulnerable to nuclear weapons, followed by long-range bombers and fighters. A single W76 air burst would damage Bear bombers on the ground over a 21-square kilometer area. Aircraft are judged least vulnerable to blast when directly facing the explosion. Table 4.12 clearly illustrates that it is necessary to detonate a W76 as a ground burst in order to destroy aircraft in concrete arch bunkers, as well POL and conventional ammunition storage.

In hard rock, a W76 ground burst is calculated to produce a crater of radius 41 meters and depth 17 meters. The W76 crater would be about 10 percent smaller in dry soil, and about twice as large if the warhead detonated over wet soil. As a result of the detonation of the W76 over hard rock, radioactive ejecta will be thrown out of the crater. At a distance of 90 meters from ground zero, the ejecta are calculated to have a depth of one meter. The runway at Ukrainka Air Base measures 3,500-meters-long by approximately 70-meters-wide in a geo-referenced Ikonos satellite image taken last year (see Figure 4.53). One W76 ground burst will be sufficient to crater the runway, making it impossible for heavy bombers to take off. Figure 4.53 is a January 17, 2000 Ikonos satellite image of the Ukrainka Air Base showing the runway pattern, revetments, and aircraft. On the satellite image, we have overlaid circles showing the radii for severely damaging the Bear bombers from the surface burst and from adjacent air bursts.

We assume that similar bombing patterns consisting of one surface burst and two air bursts would also be used in the attacks on Engels, Ryazan', and Ramenskoye, but we do not yet have the imagery or other map data to choose the ground zeros in

TABLE 4.11
Summary List of Air Base and Other Strategic Aviation Targets for MAO-NF
Target types include Air Defense Base (ADB), Arctic Staging (AS) Base, Civilian (CIV) Airfield, Strategic Bomber Base (SBB), Heavy Bomber Flight Test Center (HBFTC), Air Force Nuclear Training Center (AFNTC), Naval Aviation (NA), International Airport (IAP), Frontal (for Forward) Aviation Base (FAB), Medium Range Bomber Base (MRBB).

Level of Attack	Target Name	Target Type	Number of W76 Warheads
1	Anadyr'-Ugolnyye Kopi/ Leninka/Ugolny Airfield	ADB, AS, CIV	1
1	Engel's Airfield	SBB	3
1	Kazan State Aviation Plant	Plant, Airfield	2
1	Kuybyshev State Aviation Plant	Plant, Airfield	2
1	Ramenskoye/Zhukovskiy Airfield	HBFTC	3
1	Ryazan'/Dyagilevo Airfield	AFNTC	3
1	Tiksi Airfield	AS	1
1	Ukrainka Airfield	SBB	3
1	Vorkuta Airfield	AS	1
2	Artem N/Vladivostok/ Knevichi International Airport	NA-IAP	1
2	Bada N Airfield	FAB	1
2	Baltiysk Airfield	NA	1
2	Belaya Airfield	MRBB	1
2	Borgoy Airfield	FAB	1
2	Borzya NW Airfield	FAB	1
2	Chernyakhovsk Airfield	NA	1
2	Chita NW Airfield	UNKN	1
2	Chita/Kadala International Airport	FAB-IAP	1
2	Chkalovsk/Proveren/ Kaliningrad International Airport	NA-IAP	1
2	Domna Airfield	FAB	1
2	Galenki NE Airfield	FAB	1
2	Gorelovo Airfield	FAB	1
2	Ing-Puta Yuan-Pugoi NW Airfield	AS	1
2	Irkutsk SE/Ustinov International Airport	MRBB-IAP	1
2	Kamenka Airfield	MRBB	1
2	Khabarovsk NE/Novy/ Khabarovsk Novy International Airport	FAB-IAP	1
2	Khorol E Airfield	MRBB	1
2	Kipelovo Airfield	NA	1
2	Klin Airfield	FAB	1
2	Komsomol'sk South Airfield	FAB	1
2	Korsakov Airfield	NA	1
2	Kraskino SE Airfield	FAB	1
2	Kubinka/Tuchkvo Airfield	FAB	1
2	Lakhta/Kholm Airfield	ADB-NA-AS	1
2	Malyavr/Severomorsk-3 Airfield	NA	1
2	Marinovka Airfield	MRBB	1
2	Morozovsk SW Airfield	MRBB	1
2	Mozdok Airfield	MRBB	1
2	Nikolayevka Airfield	NA	1
2	Nivenskoye/Yezau Airfield	NA-HELO	1
2	Nyangi Airfield	FAB	1
2	Olen'ya/Olenegorsk Airfield	ADB-NA-AS	1
2	Olovyannaya Airfield	FAB	1
2	Ostrov/Gorokhovka (a) Airfield	NA-AS	1
2	Ostrov/Gorokhovka (b) Airfield	NA-AS	1
2	Petropavlovsk-Kamchatsky/ Yelizovo International Airport	NA-IAP	1
2	Romanovka W/Pristan Airfield	NA	1
2	Seshcha/Sesha Airfield	MRBB	1
2	Severomorsk/Severomorsk-1 Airfield	NA	1
2	Shatalovo/Pochinok SE Airfield	MRBB-FAB	1
2	Shaykovka/Gorodische Airfield	MRBB	1
2	Siverskiy Airfield	MRBB	1
2	Smurav'yevo/Gdov Airfield	MRBB	1
2	Sol'tsy Airfield	MRBB	1
2	Sovetskaya Gavan' Airfield	NA	1
2	Ulan-Ude/Mukhino International Airport	FAB-IAP	1
2	Unashi Airfield	FAB	1
2	Verino/Pereyaslavka Airfield	FAB	1
2	Voronezh SW/Voronezh S Airfield	MRBB-FAB	1
2	Vozdvizhenka/Ussuriysk-Vozdvizhenka Airfield	MRBB	1
2	Vozzhayevka NE Airfield	FAB	1
2	Yeysk Airfield	MRBB	1
2	Zavitinsk NE Airfield	MRBB	1

TABLE 4.12
Physical Vulnerability Data for Russian Aircraft and Other Aviation Targets
For aircraft, severe damage corresponds to: "damage which is beyond repair or requires extensive depot level repair consisting of structural failure of wings, control surfaces, fuselage, and main landing gear." For aircraft, moderate damage corresponds to: "damage to aircraft which requires extensive field level repair consisting of structural failure of control surfaces, fuselage components, and other than main landing gear such as nose, outriggers, or tail." The peak blast pressures corresponding to a 50 percent probability of achieving severe damage and the corresponding radii for air and surface bursts are computed for a 100-kiloton explosion, corresponding to the yield of the W76 warhead. Source: *NTDI Handbook,* pp. 550–551.

	VN for Severe Damage	VN for Moderate Damage	Peak Over-pressure or Dynamic Pressure for 50% Probability of Severe Damage in psi (100 kt)	Radius of Severe Damage in Meters (100 kt; burst at one kilometer height of burst)	Radius of Severe Damage in Meters (100 kt; ground burst)
Bear (TU-95) Long-range Bomber, Nose-on	12P0	12P0	10.0 (Over)	2,160	1,517
Bear (TU-95) Long-range Bomber, Random Orientation	09Q0	09Q0	0.8 (Dynamic)	2,831	2,143
Backfire Long-range Bomber, Nose-on	14P3	12P2	12.4 (Over)	1,885	1,357
Backfire Long-range Bomber, Random Orientation	11Q0	10Q1	1.6 (Dynamic)	2,035	1,578
Fishbed (MIG-21) Fighter, Nose-on	15P0	15P0	17.3 (Over)	1,404	1,152
Fishbed (MIG-21) Fighter, Random Orientation	12Q5	11Q3	1.8 (Dynamic)	2,139	1,666
Foxbat (MIG-25) Fighter, Nose-on	13P0	13P0	12.0 (Over)	1,931	1,382
Foxbat (MIG-25) Fighter, Random Orientation	12Q0	12Q6	2.3 (Dynamic)	1,949	1,542
Crusty (TU-134) Transport, Nose-on	12P0	12P0	10.0 (Over)	2,160	1,517
Crusty (TU-134) Transport, Random Orientation	09Q0	09Q0	0.8 (Dynamic)	2,831	2,143
May (IL-38) Antisubmarine Warfare Aircraft, Nose-on	12P0	12P0	10.0 (Over)	2,160	1,517
May (IL-38) Antisubmarine Warfare Aircraft, Random Orientation	09Q0	09Q0	0.8 (Dynamic)	2,831	2,143
Hind (Mi.24) Helicopter, Nose-on	08P0	07P0	4.8 (Over)	3,160	2,249
Hind (Mi.24) Helicopter, Random Orientation	07P0	06P0	4.0 (Over)	3,529	2,458
Aircraft bunker, concrete arch, inside width 11.4 meters (Failure of the arch or frame structure)	28P6	-	127.9 (Over)	—	475
Aircraft bunker, concrete arch, inside width 13.0 meters (Failure of the arch or frame structure)	32P7	-	239.0 (Over)	—	371
Aircraft bunker, concrete arch, inside width 16.0 meters (Failure of the arch or frame structure)	35P9	-	301.7 (Over)	—	340.0
Aircraft bunker, concrete arch, inside width 19.0 meters (Failure of the arch or frame structure)	30P3	-	229.8 (Over)	—	377.0
Aircraft bunker, steel A-frame, inside width 16.0 m (Failure of the arch or frame structure)	16P5	—	15.6 (Over)	1,558	1,210
POL Storage (Rupture of above-ground, exposed, steel, vertical-cylindrical tanks resulting in loss of contents)	21Q9	-	32.1 (Dynamic)	445	775
Conventional ammunition storage (Severe structural damage to munition storage igloos with 0.6 m of earth cover, resulting in light to severe damage to contents)	21P0		51.6 (Over)	122	695
BACK NET radar (Overturn)	12Q8	-	1.4 (Dynamic)	2,336	1,800
BACK NET radar (Distortion of Reflectors)	10Q4	-	0.9 (Dynamic)	2,678	2,037
SIDE NET radar (Structural Failure of Antenna Support)	11Q3	-	1.4 (Dynamic)	2,324	1,792
SIDE NET radar (Distortion of Reflectors)	10Q3	-	1.0 (Dynamic)	2,627	2,002

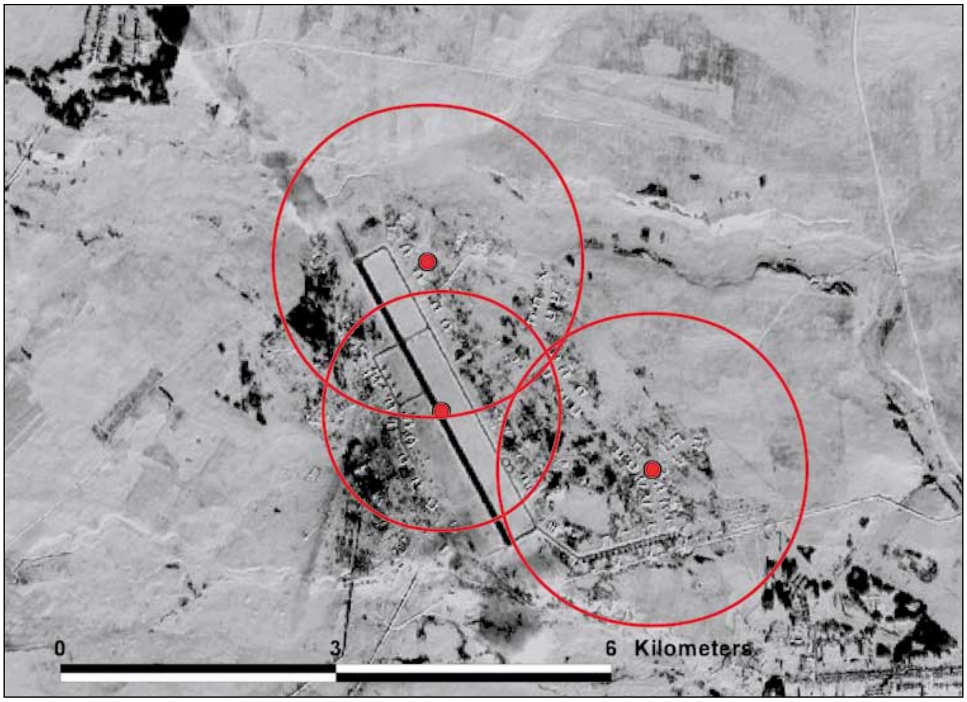


FIGURE 4.53
Air and Ground Bursts of W76 Warheads at Ukrainka Air Base
Inside the red circles the probability of destroying a Bear bomber (at a random orientation to the explosion) would be greater than 90 percent (assuming a CEP of 183 meters for 100-kt ground and air bursts). Source: spaceimaging.com.

FIGURE 4.54
Kazan State Aviation Plant
Ikonos satellite image taken on April 20, 2000. Source: spaceimaging.com.

detail, as we did for Ukrainka. Both the Kazan and Kuybyshev Aviation Plants lie on the outskirts of major Russian cities. Figure 4.54 shows an Ikonos satellite image of the Kazan plant and adjacent airfield (Kazan North). In NRDC's MAO-NF, we assign a W76 ground burst to each plant and to the airfields adjacent to the plants. For forward and dispersal air bases in MAO-NF, we assign one 100-kt W76 ground burst at the center of each runway to crater it. Aircraft adjacent to the runway will have been destroyed, and since strategic bombers can't land or take off from the damaged airfield, any surviving aircraft would essentially be trapped. Fuel stores associated with the airfield, such as underground tanks, would therefore be rendered useless.

Casualties and Sensitivity Analysis

Figures 4.55 and 4.56 show the summary casualty data for the first and second levels of attack, respectively, against Russian strategic aviation targets as a function of warhead fission fraction and population sheltering. As we will see in the concluding section of this chapter, the attack on this component of Russia's nuclear forces represents the second-greatest threat to civilians, following the attack on Russian ICBM silos. The numbers of computed casualties decreases significantly under the assumption of residential sheltering, but does not continue to decrease substantially for multi-story or basement sheltering. This is due to the fact that most of the MAO-NF strategic aviation targets are quite close to urban areas. Figures 4.57 and 4.58 plot the casualties and fatalities by month for the first and second levels of attack, respectively, against Russian strategic aviation targets. Figure 4.59 maps the fallout patterns for the attack on priority (i.e., first level) Russian aviation targets in the vicinity of Moscow. We calculate an average of one million civilian casualties in the first level of attack and an average of two million civilian casualties in the second level of attack.

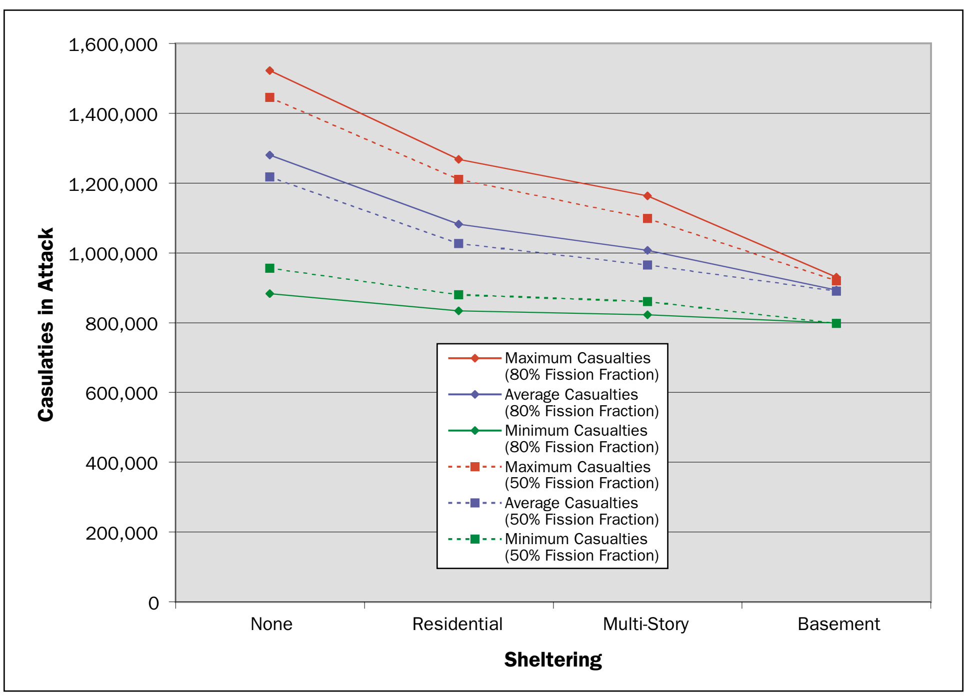


FIGURE 4.55
Summary Casualty Data for the First Level of Attack on Russian Long-Range Bomber Bases and Facilities

FIGURE 4.56
Summary Casualty Data for the Second Level of Attack on Russian Long-Range Bomber Bases and Facilities

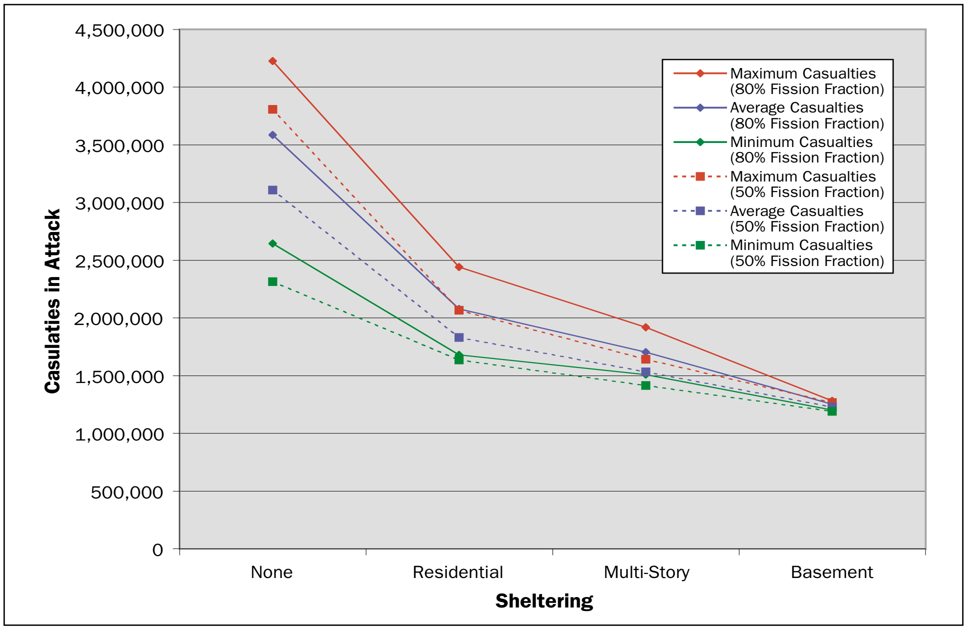


FIGURE 4.57
Monthly Variation in Casualties and Fatalities for the First Level of Attack on Russian Long-Range Bomber Bases and Facilities
Using the assumptions of no sheltering and a warhead fission fraction of 50 percent.

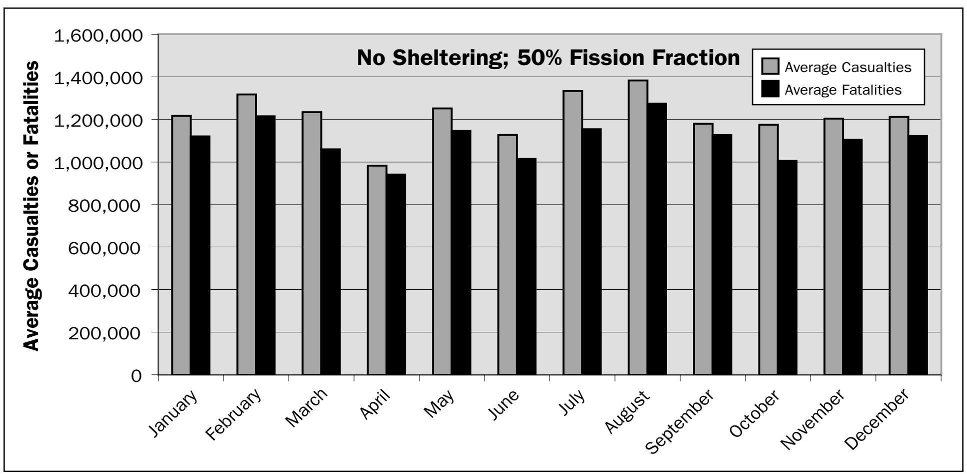
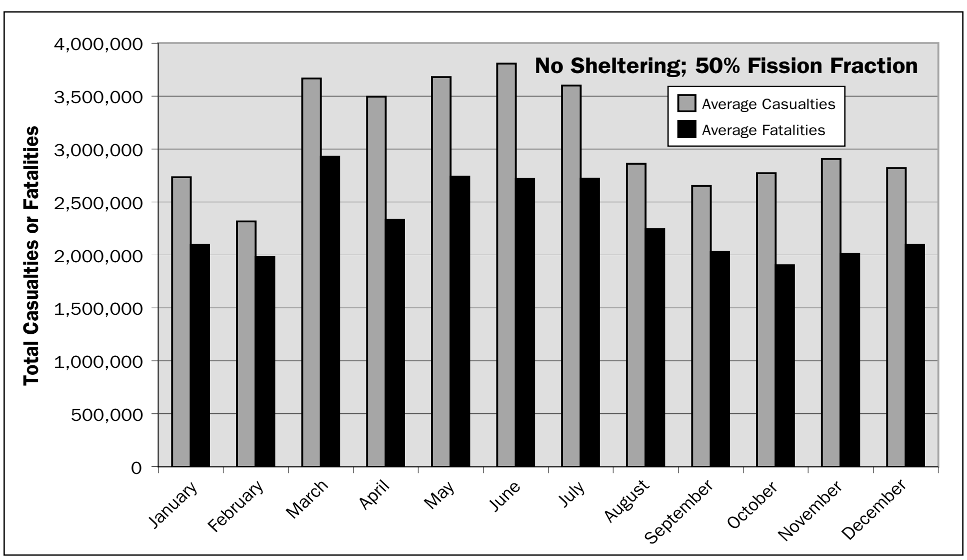


FIGURE 4.58
Monthly Variation in Casualties and Fatalities for the Second Level of Attack on Russian Long-Range Bomber Bases and Facilities
Using the assumptions of no sheltering and a warhead fission fraction of 50 percent.



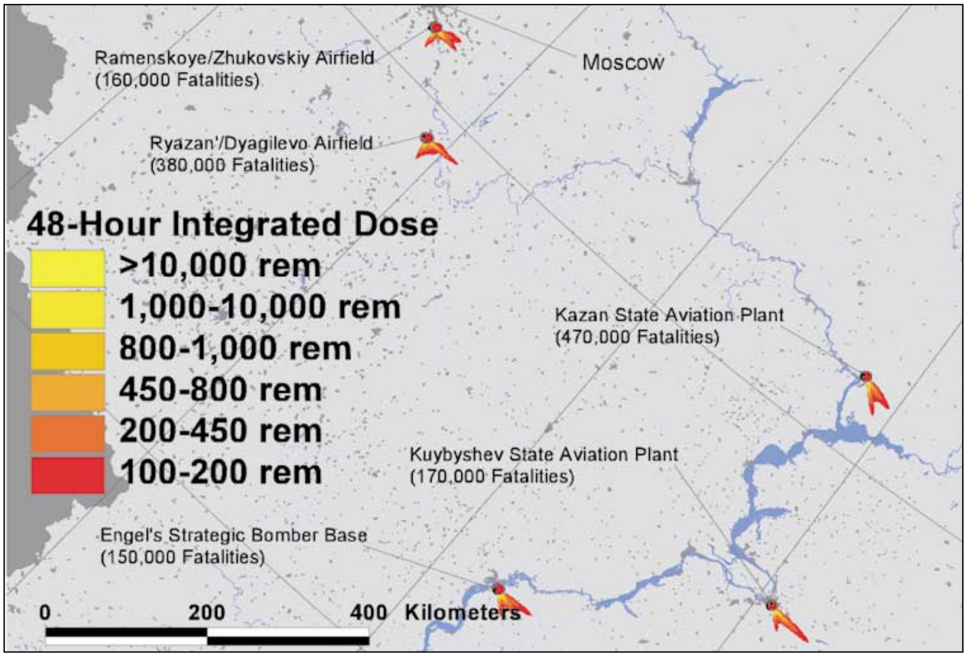


FIGURE 4.59
Fallout Patterns for Strategic Aviation Targets in the Moscow Area
From the first level of attack in NRDC's MAO-NF. This calculation uses the most probable wind patterns for the month of July, and assumes that the attacking W76 warheads have a fission fraction of 80 percent and the population is unsheltered.

NUCLEAR WEAPON STORAGE SITES

Description of Targets

The U.S. government does not know how many intact nuclear warheads are in Russia. The total number of nuclear warheads may be as great as 20,000, 6,000 of which are deployed with strategic forces. The number of non-strategic nuclear warheads is said to be between 6,000 and 13,000, with the actual number more likely near the upper limit.[58] It is not known outside of Russia, at least not by us, how many nuclear warheads are in storage awaiting disassembly.

We also do not know precisely how many nuclear warhead storage facilities Russia has. The U.S.-Russian Cooperative Threat Reduction Program (CTR, also referred to as the "Nunn-Lugar Program") and the Russian press refer to 123 nuclear weapon storage sites.[59] In a report on the CTR effort, *Tass* refers to "guarding the perimeters of 123 nuclear weapons depots, including 50 facilities of the Russian Defense Ministry."[60] A second *Tass* report refers to "123 nuclear weapons stores, [including] 23 Russian Strategic Missile Troops sites and 48 navy and air force facilities."[61] And a U.S. General Accounting Office (GAO) report indicates that, in response to a 1999 request from the Russian Navy, the U.S. Department of Energy is installing security systems at 42 Russian naval sites that store nuclear weapons.[62] While the 12th Main Directorate for Nuclear Weapons (12th GUMO) may have a presence at all nuclear warhead storage sites, these citations suggest that under the Ministry of Defense there are:

50 sites managed by the 12th Main Directorate
42 sites managed by the Navy[63]
23 sites managed by the Strategic Rocket Forces
8 sites managed by the Air Forces
123 sites total

Even if one accepts these numbers, it is unclear from the references how "site," "depot," and "facility" are defined—do these terms refer to a high-security area, one of perhaps several bunkers or buildings within a security area, or a larger site that may contain several such areas? We suspect that in the references above, it is the first: each refers to a high-security fenced area under guard.

The 50 sites managed by the 12th Main Directorate can be further subdivided into:

- National-level storage sites
- Regional level storage sites, also called rocket/repair technical bases (RTBs)
- Storage sites at nuclear weapon assembly/disassembly plants[64]

We are not able to identify all 123 storage sites, but in Table 4.13 and Figure 4.60, we list the 64 sites we have identified through a variety of open sources.

The Russian press recently provided a general description of Russian nuclear weapon storage sites.

> *Such installations are surrounded by two zones: an unprotected general zone and a protected "technical" zone. But that "protection" amounts to three barbed-wire barriers that, as a rule, are not connected to any alarm system. Within the technical zone, immediately surrounding the facility, there is another, "local" zone that's supposed to be secured 24 hours a day. But in reality the alarm sensors function at 50 percent of capacity at best.*[65]

In Figure 4.61, we represent our understanding of the layout of a typical national-level, nuclear weapons storage site managed by the 12th Main Directorate.

The Belgorod-22 (Golovchino) national nuclear weapon storage site is located about 17 kilometers from the Russian-Ukrainian border. Figure 4.62 is a map of Belgorod-22 derived from NRDC's analysis of a 1970 Corona satellite image (courtesy of Joshua

FIGURE 4.60
Known or Presumed Nuclear Weapon Storage Sites in Russia

Handler, Princeton University) and a contemporary U.S. JOG. Snow is visible on the ground in the Corona image except in the forested areas that are nearly identical in shape on the JOG. The Vorksa River flows in an inverted "V" just above a village labeled "Topoli" on the JOG, and the inverted-V-shaped bend in the Vorksa is faintly visible in the Corona image with its snow and ice covering. On the JOG, the road, which runs past Topoli, continues into the forested region and then forms a circle. In the Corona image, five to seven discrete nuclear weapon storage locations are visible as snow-covered patches spaced 300–700 meters apart along this circular road. Interestingly, no troop declarations are given for this area in the CFE data exchange.

Corona satellite images from three additional nuclear weapon storage sites in the Ural Mountains—Karabash (Mission 1115-1 of September 14, 1971), Nizhnyaya Tura (Mission 1016-2 of January 21, 1965) and Yuryuzan (Mission 1115-2 of September 20, 1971)—were also made available to NRDC by Joshua Handler. We geo-referenced these images to the corresponding JOGs using common features such as roads, railroads, streams and lakes. This enabled us to extract an overall length

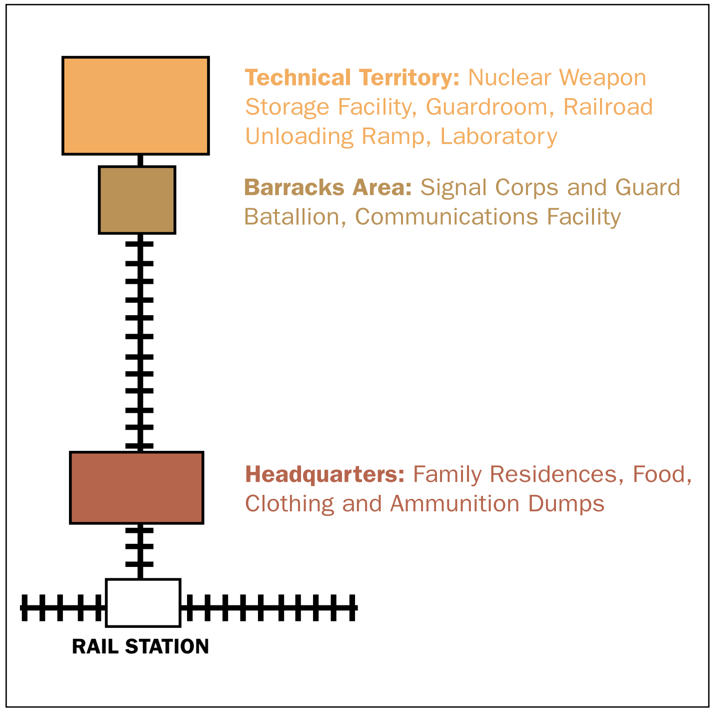
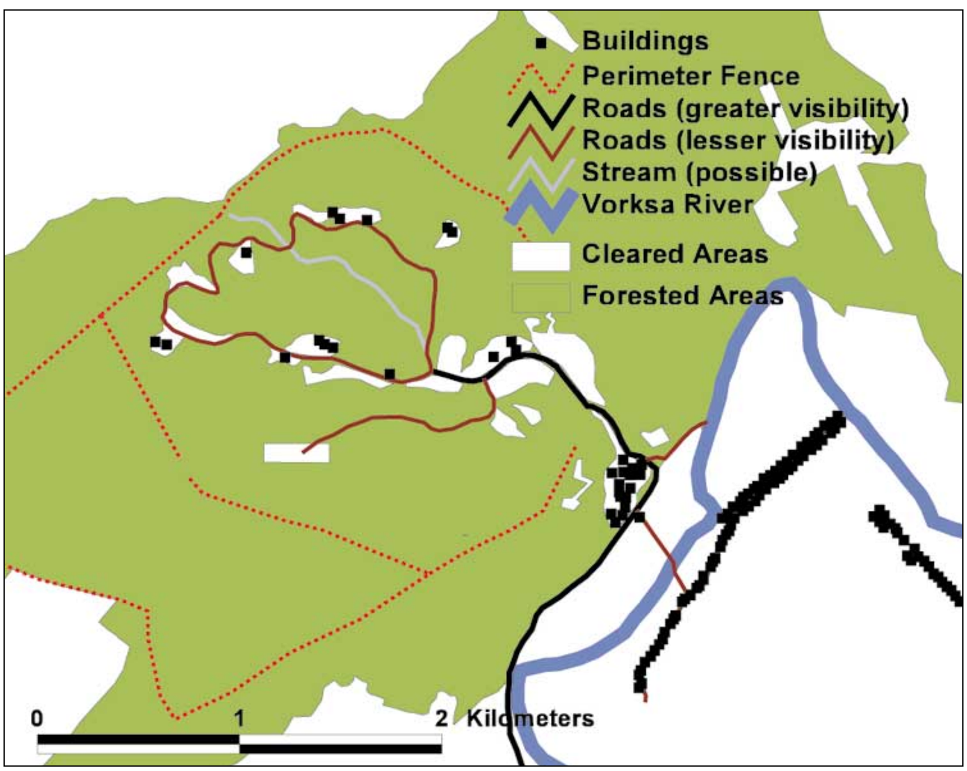


FIGURE 4.61 ▲
General Schematic of a Russian Nuclear Weapon Storage Site



◀ FIGURE 4.62
A Map of the Belgorod-22 Nuclear Weapon Storage Site
Located near the Russian-Ukrainian border.

TABLE 4.13
Known or Presumed Operational Nuclear Weapon Storage Sites in Russia
For four of these nuclea weapon storage sites, marked by an asterisk in the table, we do not yet have accurate coordinates.

Nuclear Warhead Storage Site Name	City, Region	Military District
	National Level Storage Sites Maintained by the 12th Main Directorate	
Belgorod-22 Technical Territory	Golovchino, Belgorod region	Moscow
Bryansk-18 (Zhukovka) Technical Territory	Rzhanitsa, Bryansk Region	Moscow
Irkutsk-XX Technical Territory	Zanina (South of Zalari), Irkutsk Oblast	Transbaikal
Karabash/Chelyabinsk-XX Technical Territory	Karabash, Chelyabinskaya Oblast	Urals
Khabarovsk-XX Technical Territory	Khabarovsk, Khabarovsk Kray	Far East
Komsomolsk-na-Amure-XX Technical Territory	Bolon, South of Komsomol'sk-na-Amur, Khabarovsk Kray	Far East
Krasnoyarsk-26 Technical Territory	Dodonovo, Krasnoyarskiy Kray	Siberian
Mozhaysk-XX Technical Territory	Mozhaysk, Moskovskaya Oblast	Moscow
Murmansk-XX (Olenegorsk) Technical Territory	Olenegorsk, (East of) Murmanskaya Oblast	Northern
Nizhniy Tagil-XX (Nizhnyaya Tura) Technical Territory, Site 1	Lesnoy, Nizhnaya Tura, Yekaterinburgskaya Oblast	Urals
Nizhniy Tagil-XX (Nizhnyaya Tura) Technical Territory, Site 2	Nizhnyaya Tura, (Southwest of) Yekaterinburgskaya Oblast	Urals
Saratov-XX (Krasnoarmeyskoye) Technical Territory	Engel's, Saratovskaya Oblast	Volga
Sebezh-XX (Bulyzhino) Technical Territory	Bulyzhino, Pskovskaya Oblast	Northern
Sverdlovsk-XX Technical Territory*	Sverdlovsk, Yekaterinburgskaya Oblast	Urals
Vologda-XX (Chebsara) Technical Territory	Chebsara, Vologodskaya Oblast	Northern
Voronezh-XX (Borisoglebsk) Technical Territory	Borisoglebsk, Voronezhskaya Oblast	Moscow
Yuryuzan Technical Territory	Trekhgornyy, South of Yuryuzan', Chelyabinskaya Oblast	Urals
	Sites at Nuclear Weapon Assembly/Disassembly Plants	
Penza-19 Site 1 (Bermed Structures) Nuclear Warhead Storage Facility	Zarechnyy/Seliksa, 13 km East of Penza, Penzenskaya Oblast	Volga
Sarov-Avangard Nuclear Warhead Storage Facility	Sarov, Mordovskaya Republic	Volga
	Sites Managed by the Navy or the 12th GUMO	
Konyushkov Bay/Abrek Bay Nuclear Warhead Storage Facility	Tikhookeanskiy; SE of Vladivostok, Primorskiy Kray	Far East
Lakhta/Kholm Airfield Nuclear Warhead Storage Facility	Arkhangel'skaya Oblast	Northern
Olen'ya/Olenegorsk Airfield Nuclear Warhead Storage Facility	Olenegorsk, Murmanskaya Oblast	Northern
Ostrov Airfield Nuclear Warhead Storage Facility	Ostrov, Pskovskaya Oblast	Northern
Primorskiy area Nuclear Warhead Storage Facility*	Unknown	Far East
Rybachiy peninsula/Petropavlovsk area (Military Unit 95051)	Krasheninnikova Bay, Kamchatskaya Oblast Nuclear Warhead Storage Facility	Far East
Severodvinsk Nuclear Warhead Storage Facility	Severodvinsk, Arkhangel'skaya Oblast	Northern
Sovetskaya Gavan' Airfield Nuclear Warhead Storage Facility*	Sovetskaya Gavan', Khabarovskiy Kray	Far East
St. Petersburg Area Nuclear Warhead Storage Facility	St. Petersburg area, Leningradskaya Oblast	Northern
	Sites Managed by the Strategic Rocket Forces	
Aleysk-XX RTB	Aleysk, Altayskiy Kray	Siberian
Barnaul-XX RTB	Barnaul, Altayskiy Kray	Siberian
Bershet'-XX RTB	Bershet', Perm' Oblast	Urals
Dombarovsky-XX RTB	Dombarovskiy, Orenburgskaya Oblast	Volga
Drovyanaya-XX RTB	Drovyanaya, Aginski Buryat A. Okrug	Transbaikal
Irkutsk-XX RTB	Irkutsk, Irkutsk Oblast	Transbaikal

Nuclear Warhead Storage Site Name	City, Region	Military District
Kansk-XX RTB	Kansk, Krasnoyarskiy Kray	Siberian
Kartaly-XX RTB	Kartaly, Chelyabinskaya Oblast	Urals
Kostroma-XX RTB	Kostroma, Kostromskaya Oblast	Moscow
Kozelsk-XX RTB	Kozelsk, Kaluzhskaya Oblast	Moscow
Krasnoyarsk-XX (Achinsk) RTB	Krasnoyarsk, Krasnoyarskiy Kray	Siberian
Nizhniy Tagil-XX RTB	Nizhiy Tagil, Yekaterinburgskaya Oblast	Urals
Novosibirsk-XX RTB	Novosibirsk, Novosibirskaya Oblast	Siberian
Tatishchevo-5 RTB	Tatishchevo, Saratovskaya Oblast	Volga
Teykovo-XX RTB	Teykovo, Ivanovo Region	Moscow
Uzhur-XX RTB	Uzhur, Krasnoyarskiy Kray	Siberian
Vypolzovo-XX RTB	Vypolzovo, Tver' Oblast	Moscow
Yoshkar-Ola-XX RTB	Yoshkar-Ola, Mariyskaya Republic	Volga
Yur'ya-XX RTB	Yur'ya, Kirovskaya Oblast	Urals
Sites Managed by the Air Forces or the 12th GUMO		
Belaya Airfield Nuclear Warhead Storage Facility	Mikhaylovka, Irkutsk Oblast	Transbaikal
Engels Airfield Nuclear Warhead Storage Facility	Engel's, Saratovskaya Oblast	Volga
Irkutsk Airfield Nuclear Warhead Storage Facility*	Irkutsk, Irkutsk Oblast	Transbaikal
Kaliningrad/Chernyakhovsk Airfield Nuclear Warhead Storage Facility	Kaliningrad Region	Moscow
Kamenka Airfield Nuclear Warhead Storage Facility	Kamenka, Penzenskaya Oblast	Volga
Khorol East Airfield Nuclear Warhead Storage Facility	Khorol', Primorskiy Kray	Far East
Ryazan/Dyagilevo Airfield Nuclear Warhead Storage Facility	Ryazan', Ryazanskaya Oblast	Moscow
Seshcha/Sesha Airfield Nuclear Warhead Storage Facility	South-East of Roslav', Bryansk Region	Moscow
Shatoalovo/Pochinok SE Airfield Nuclear Warhead Storage Facility	Pochinok, (South of) Smolensk Oblast	Moscow
Shaykovka/Gorodische Airfield Nuclear Warhead Storage Facility	Gorodische, Smolensk Oblast	Moscow
Siverskiy Airfield Nuclear Warhead Storage Facility	Siverskiy, Leningradskaya Oblast	Northern
Smurav'yevo/Gdov Airfield Nuclear Warhead Storage Facility	Gdov, Pskovskaya Oblast	Northern
Sol'tsy Airfield Nuclear Warhead Storage Facility	Sol'tsy, Novgorodskaya Oblast	Northern
Ukrainka Airfield Nuclear Warhead Storage Facility	Vernoye, Amurskaya Oblast	Far East
Voronezh SW/Voronezh S Airfield Nuclear Warhead Storage Facility	South of Voronezh, Voronezhskaya Oblast	Moscow
Vozdvizhenks Airfield Nuclear Warhead Storage Facility	North of Ussuriysk, Primorskiy Kray	Far East
Zavitinsk NE Airfield Nuclear Warhead Storage Facility	Zavitinsk, Amurskaya Oblast	Far East

scale for the images and to assess the likely spacing of bunkers for Soviet-built nuclear weapon storage sites. This process was limited in accuracy of course by the vintage of the satellite images and the reasonable guesses that had to be made regarding identification of bunkers. We also had to make assumptions about the spacing of bunkers and their hardness in order to construct the MAO-NF attack, as discussed below.

Warhead Requirements and Aimpoints

The NTDI Handbook lists target category 604 X0, "assembly and storage facilities for nuclear weapons and components,"[66] and the current U.S. Intelligence Data Handling System lists target categories 604 00, "Nuclear Weapons Storage," and 604 20, "Nuclear weapons storage site, operational," suggesting continuity between them.

The NTDI Handbook describes severe and moderate damage for 13 underground or earth-mounded storage structures, (see Table 4.14). We assume that the "national bunker" structure type refers to the Soviet-built national, nuclear weapon storage sites discussed above. We found an example of a "Type III (Cruciform)" storage bunker in a declassified 1963 CIA Photographic Intelligence Report: "Regional Nuclear Weapons Storage Site Near Berdichev, USSR."[67] This report discusses the similarity between cruciform bunkers near Berdichev in present-day Ukraine, and near Dolon Airfield in present-day Kazakhstan. As the name suggests, the storage bunkers are cross-shaped, earth-mounded, drive-through buildings measuring 60 by 53 meters. The two cruciform bunkers at Berdichev were measured to be 990 meters apart.

Casualties and Sensitivity Analysis

We explore an attack by eight W76 warheads on each of the 17 National-Level nuclear weapon storage sites (136 warhead for a total yield of 13.6 Mt), and take into

TABLE 4.14
Physical Vulnerability Data for Soviet-Built Nuclear Weapon Storage Facilities
A CEP of 130 meters and ground bursts were assumed for the W88 and W76 damage radius calculations. Source for the vulnerability numbers: *NATO Target Data Inventory Handbook* (1989)

Type	VN, Severe Damage	Severe Damage Radius, 475-kt W88 (m)	Severe Damage Radius, 100-kt W76 (m)	VN, Moderate Damage	Moderate Damage Radius, 475-kt W88 (m)	Moderate Damage Radius, 100-kt W76 (m)
National bunker	46P8	299	156	44L8	330	171
Direct support bunker	46P8	299	156	44L8	330	171
Type I (Nuclear Capable)	36L9	649	308	34L9	739	353
Type II (Guitar)	36L9	649	308	34L9	739	353
Type III (Cruciform)	36L9	649	308	34L9	739	353
Type IV (ASM)	36L9	649	308	34L9	739	353
Type V (ASM MOD)	36L9	649	308	34L9	739	353
Type VI	37P9	615	296	31P7	751	398
Type VII (Arys Mod)	34L9	739	353	31L6	679	371
Type VIII	34P7	606	323	30P5	712	397
Type XI (Arys)	44L7	304	163	43L7	324	174
Type VIII (Single Bay)	34P1	468	276	30P5	712	397
Vault	38P1	360	212	34P1	468	276

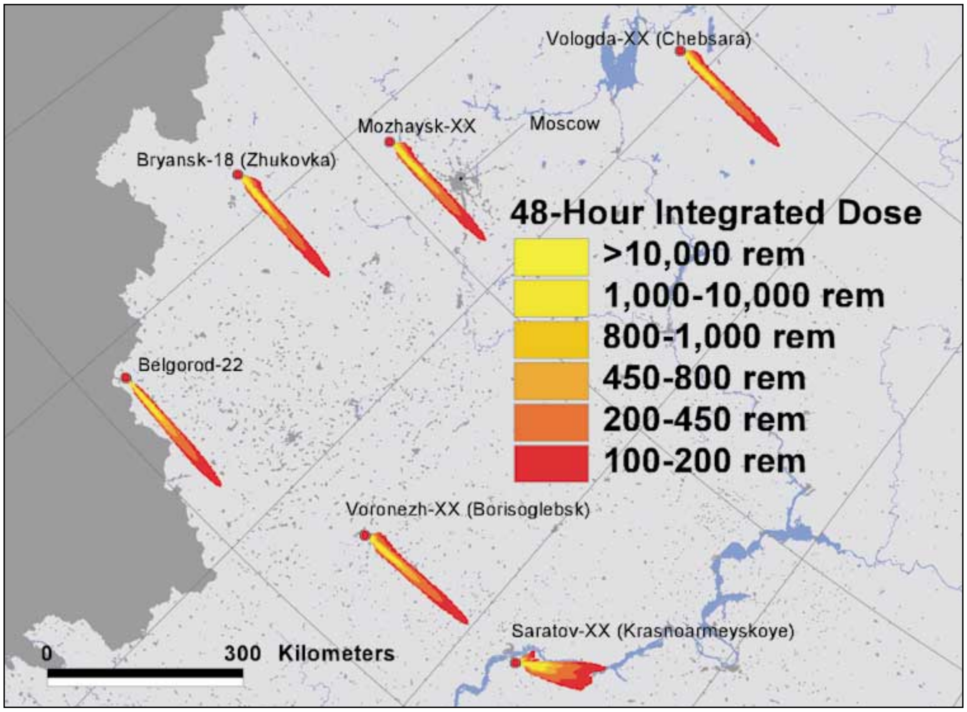


FIGURE 4.63
A Map of the Attack on the National-Level Storage Sites in the Vicinity of Moscow
In this calculation six storage sites are attacked by a total of 48 W76 warheads with a total yield of 4.8 megatons. The most probable winds for the month of November are used in the calculation. We assumes warhead fission fractions of 80 percent and an unsheltered population. A total of 1.4 million casualties are calculated, including 870,000 fatalities.

account seasonal variations in the wind, fission fractions of the weapons, and sheltering of the population. Because of the high weapon requirement for warhead storage sites, and because these targets do not need to be destroyed within an urgent timeframe under the likely guidance in the SIOP, an attack on only 17 sites is probably indicative of the U.S. warhead assignment in the actual SIOP and is what we model in our MAO-NF.

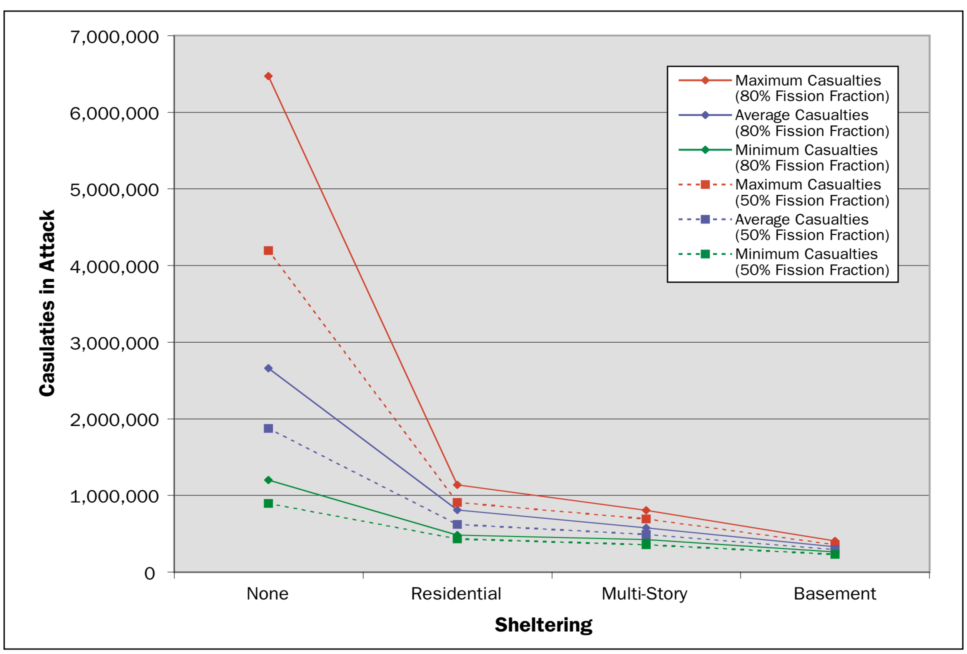


FIGURE 4.64
Summary Casualty Data for an Attack on the Russian National-Level Nuclear Warhead Storage Sites as a Function of Population Sheltering

FIGURE 4.65
Monthly Variation in Casualties and Fatalities for an Attack on the Russian National-Level Nuclear Warhead Storage Sites

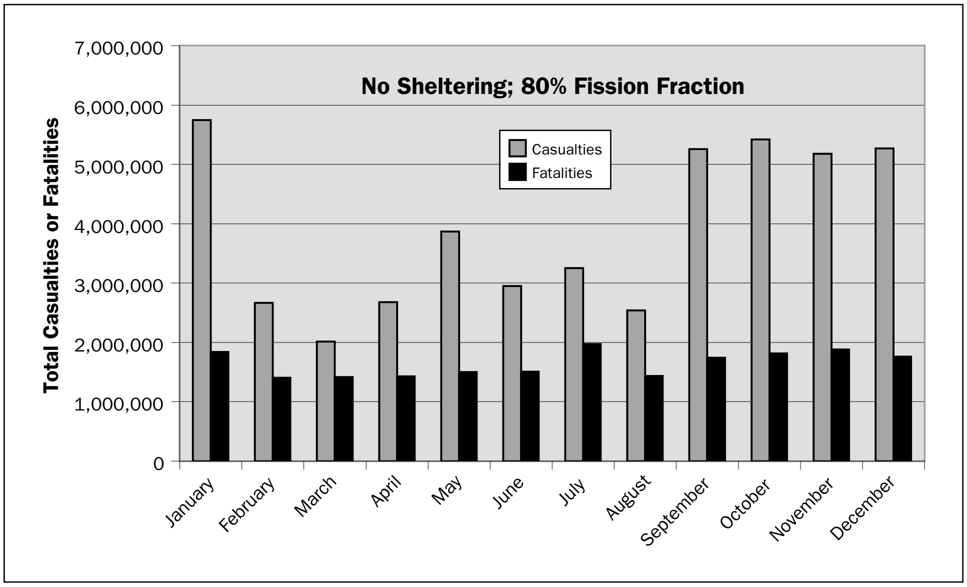


Figure 4.63 displays the nuclear warhead storage targets in the central and southern portions of European Russia, and the associated fallout patterns from the MAO-NF attack. Figure 4.64 provides a summary of the casualty calculations for the attack on the national-level nuclear warhead storage sites. As the figure illustrates, even a minimal level of population sheltering during the first 48 hours after the attack drastically reduces the number of computed casualties. We compute that between 355,000 and 1.1 million civilian casualties result from the MAO-NF attack on Russian national-level nuclear warhead storage sites, including between 290,000 and 740,000 fatalities. As we will see in the concluding section of this chapter, this component of Russia's nuclear forces ranks third in terms of a threat to civilians.

THE NUCLEAR WEAPON DESIGN AND PRODUCTION COMPLEX

Description of Targets

The core of the Russian (and formerly Soviet) nuclear weapon design and production complex is composed of ten closed cities and one open city (see Figure 4.66 and Table 4.15). What transpired at these locations throughout the Cold War was a central security concern for the United States and West Europe for more than 40 years.[68] This complex researched, developed, tested, and produced the nuclear weapons that were provided to Soviet armed forces and that were deployed widely against western militaries. As these secret cities were discovered through U.S. intelligence means beginning in the 1950s, they became some of the highest priority targets of U.S. nuclear forces. No doubt many or all remain on the target list today.

The Russian government continues to operate the complex at a much reduced pace, but with high levels of security. As satellite imagery and declassified U.S. military maps reveal, certain plants are extremely large and most of the facilities have extensive fencing. The ten closed cities that make up the complex have a combined population of three-quarters of a million people, and the population of the

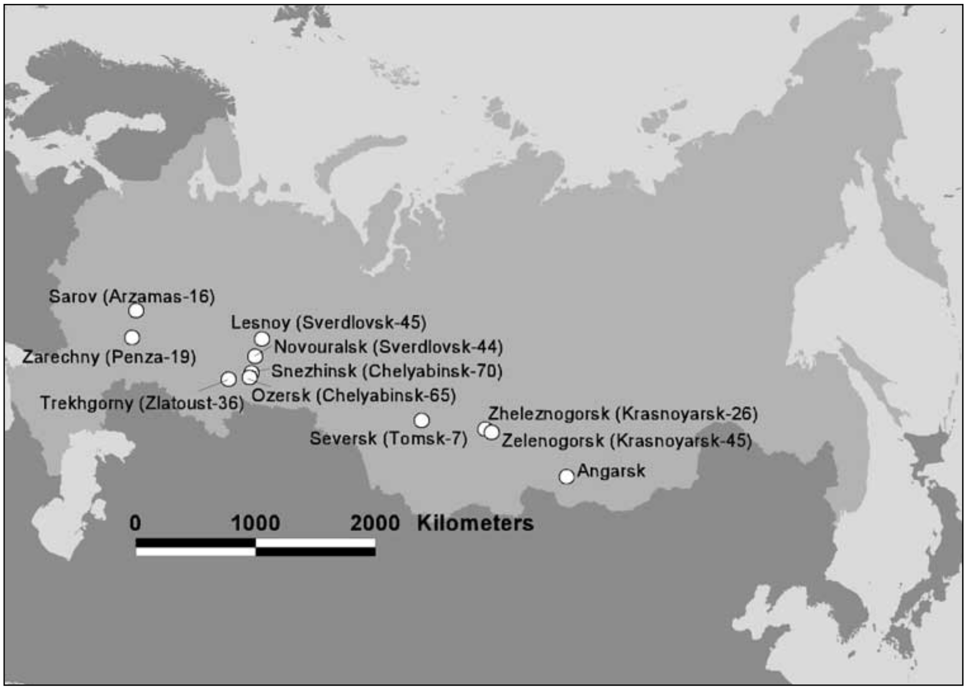


FIGURE 4.66
The Ten Closed Cities and One Open City (Angarsk) of the Russian Nuclear Weapon Design and Production Complex

open city of Angarsk was 286,000 in 1989. Only a fraction of those people, an estimated 67,000, perform nuclear program work and are paid out of the Ministry of Atomic Energy's (Minatom) budget.[69]

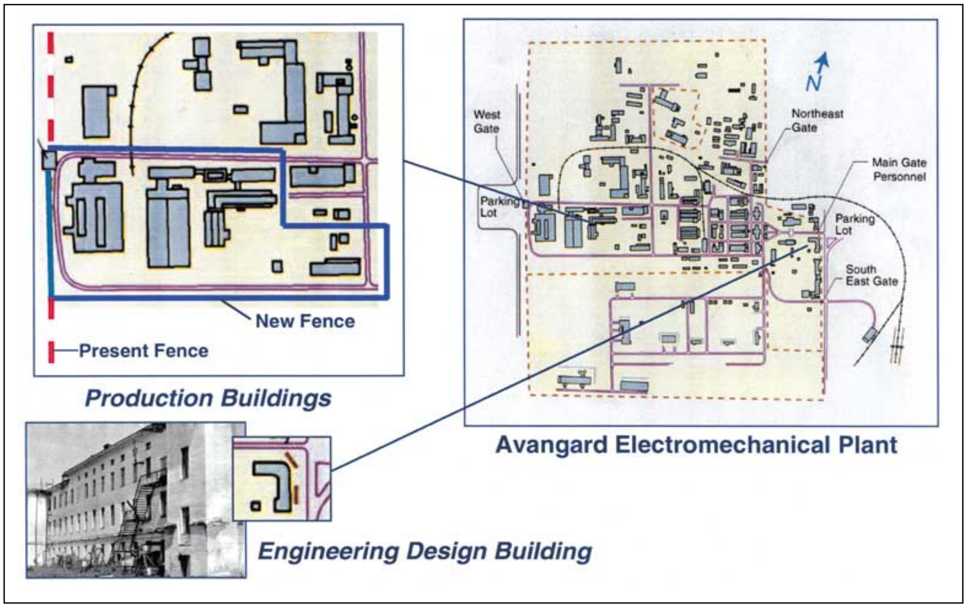
Attacking the complex would destroy key facilities that contribute to the research, development, and production of Russia's nuclear weapons. The goal of an attack on the Russian nuclear weapons complex would be to eliminate any future nuclear weapon design and production capability. The attacked facilities include design laboratories, plutonium and tritium production reactors, chemical separation plants, uranium enrichment plants, warhead assembly, and component plants. It should be said that the level of activity at many of the sites is quite low compared to past decades, and some of the facilities at these sites are shut down.

Warhead Requirements and Aimpoints

Our MAO-NF counterforce attack theoretically does not target cities as such. That there are always attractive military targets in urban areas poses a dilemma for nuclear war planners, whose guidance may be to avoid civilian casualties as much as possible. As we show in the next section, this issue is especially pronounced for attack scenarios that call for hitting command, control, and communication targets, which are often in the middle of cities. In fashioning an attack against the Russian nuclear weapons design and production complex, we are confronted with a similar problem of what facilities to target, and how to target them. With tens of thousands of people living in close proximity to the plants and laboratories, an attack using even a single weapon will result in large numbers of casualties.

For purposes of attacking facilities in the Russian nuclear weapons design and production complex, the NTDI Handbook lists four relevant target categories:

FIGURE 4.67
The Sarov Avangard Warhead Production Plant
This production plant is also the target shown in the lower left corner of Figure 4.68. Source: Los Alamos National Laboratory View-Graph.



▶ Nuclear reactors used for the production of fissionable materials and for the generation of heat
▶ Installations for the production of uranium-235 and lithium, which are used primarily in weapons
▶ Installations that perform research and development, design, and fabrication of fissionable material components and related nuclear components of weapons
▶ Assembly and storage facilities for nuclear weapons and components[70]

The general vulnerability numbers for severe and moderate damage are provided for the third category:

FIGURE 4.68
Sarov
Ikonos satellite image taken on February 26, 2000, and displayed here at 16-meter resolution. The plume in the center of the image originates at the location of the test reactor area of the laboratory, just southeast of the Design Bureau (upper right target) and directly east of the Avangard warhead production plant (lower left target). The inner white circles correspond to the severe damage radii and the outer white circles correspond to the moderate damage radii for a 100 kt warhead at a height of burst of 400 meters. Source: spaceimaging.com.

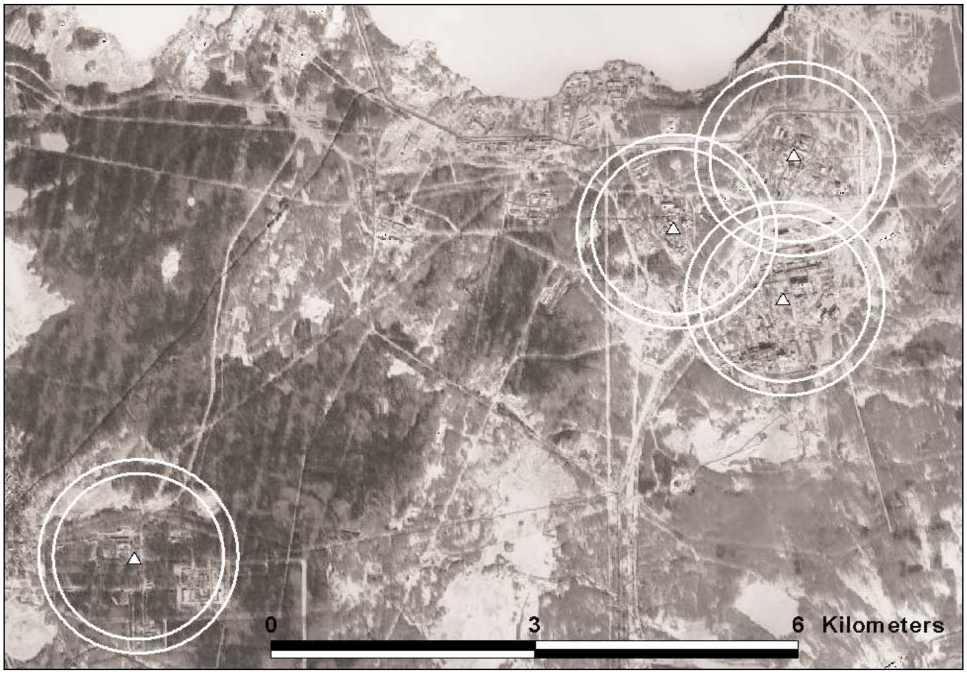
TABLE 4.15
Targeting Information for the Russian Nuclear Weapons Design and Production Complex

Contemporary Name	Soviet Designation	Function	Workforce[72]	Population[73]	Number of W76 Warheads
Sarov	Arzamas-16	Nuclear Weapons Design; Serial Production of Nuclear Weapons	21,500	83,000	2
Snezhinsk	Chelyabinsk-70	Nuclear Weapons Design	15,000	48,000	4
Lesnoy	Sverdlovsk-45	Serial Production of Nuclear Weapons	10,000	58,000	4
Zarechny	Penza-19	Serial Production of Nuclear Weapons	11,000	64,000	1
Trekhgorny	Zlatoust-36	Serial Production of Nuclear Weapons	6,400	33,000	2
Ozersk	Chelyabinsk-65	Tritium Production (Reactors, Reprocessing, Waste, MOX Fuel Fabrication); Plutonium and Tritium Warhead Component Fabrication	12,000	88,000	4
Seversk	Tomsk-7	Plutonium Production (Reactors and Reprocessing); HEU Production; Plutonium and HEU Warhead Component Fabrication	15,000	119,000	5
Zheleznogorsk	Krasnoyarsk-26	Plutonium Production (Reactors and Reprocessing)	8,300	100,000	2
Zelenogorsk	Krasnoyarsk-45	HEU Production	10,000	67,000	1
Novouralsk	Sverdlovsk-44	HEU Production	15,000	96,000	3
Angarsk	Angarsk (?)	Uranium Enrichment	?	286,000 (1989 Soviet Census)	1

TABLE 4.16
Casualty and Fatality Data for the Attack on the Russian Nuclear Weapons Design and Production Complex

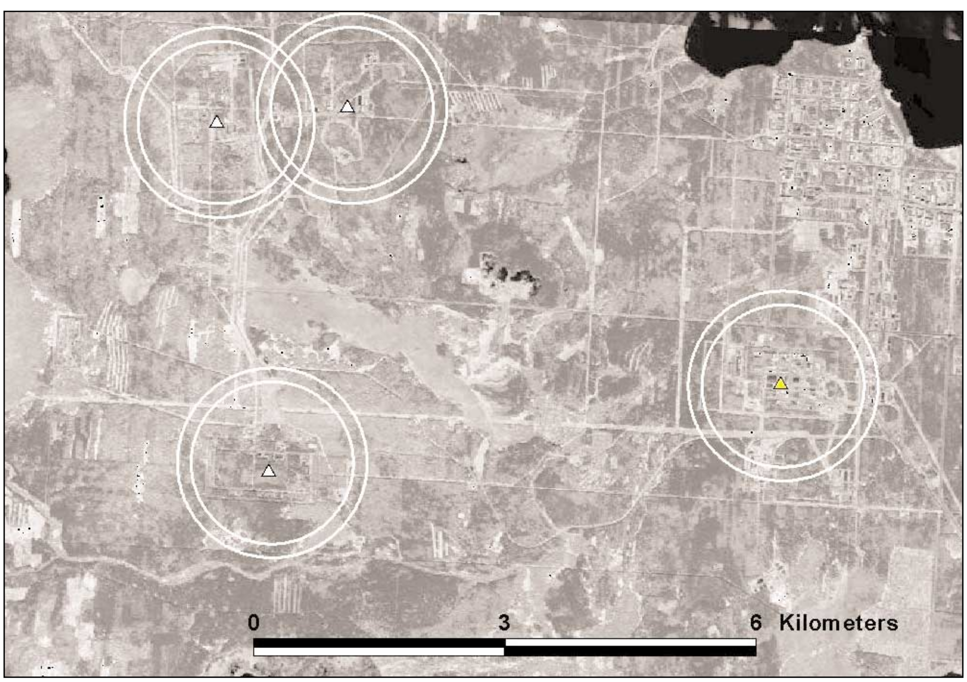
City Name	Population[74]	Casualties, Blast Model	Fatalities, Blast Model	Fatalities, Superfires Model	Number of W76 Warheads
Sarov	83,000	73,000	35,000	89,000	2
Snezhinsk	48,000	6,500	1,600	7,500	4
Lesnoy	58,000	62,000	43,000	58,000	4
Zarechny	64,000	20,000	11,000	21,600	1
Trekhgorny	33,000	7,400	1,700	6,100	2
Ozersk	88,000	11,500	3,400	5,900	4
Seversk	119,000	60,000	26,000	56,500	5
Zheleznogorsk	100,000	1,000	400	1,000	2
Zelenogorsk	67,000	7,000	1,400	8,600	1
Novouralsk	96,000	30,000	16,000	31,000	3
Angarsk	286,000 (1989 Soviet Census)	72,500	7,500	85,000	1
Summary	946,000	350,900	147,000	370,200	29

FIGURE 4.69
Ozersk
Ikonos satellite image taken on February 24, 2000, and displayed here at 16-meter resolution. The frozen lake at the top center-right is Lake Kyzyltash. Targets include the plutonium pit production facility, plutonium production reactors (shut down), tritium production reactors (operating), and fissile material storage areas. The inner white circles correspond to the severe damage radii and the outer white circles correspond to the moderate damage radii for a 100 kt warhead at a height of burst of 400 meters. Source: spaceimaging.com.



VN 19Q7 predicts severe damage to the installation consisting of severe damage to the principal production building, severe damage to machinery and equipment in the building and associated damage generally as follows: severe damage to supplies, parts and assemblies in process and finished products; severe damage to electric switches and circuit breakers; collapse of switchyard frames; collapse of overhead gas mains; and interruption of water supply due to electric power loss.

FIGURE 4.70
Snezhinsk
Ikonos satellite image taken on July 18, 2000, and displayed here at 16-meter resolution. The targets include the Site 20 reactor area, the Site 9 theoretical division (nuclear weapons design) and the Site 10 explosives plant. The inner white circles correspond to the severe damage radii and the outer white circles correspond to the moderate damage radii for a 100 kt warhead at a height of burst of 400 meters. Source: spaceimaging.com.



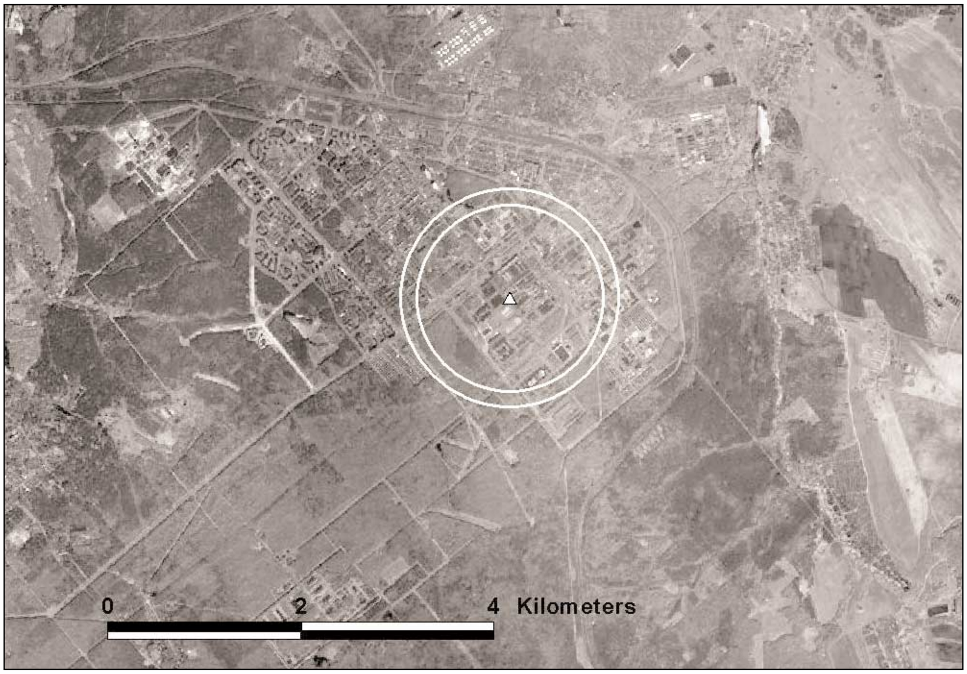


FIGURE 4.71
Zarechny
Ikonos satellite image taken on June 12, 2000, and displayed here at 16-meter resolution. We have targeted the Start Production Association nuclear warhead component fabrication and nuclear warhead assembly plant. The inner white circle corresponds to the severe damage radius and the outer white circle corresponds to the moderate damage radii for a 100 kt warhead at a height of burst of 400 meters. Source: spaceimaging.com.

VN 17Q7 predicts moderate damage to the installation consisting of at least moderate structural damage to the principal production building, moderate damage to machinery and equipment in the building and associated damage generally as follows: moderate to severe damage to supplies, parts and assemblies in process and finished products, severe damage to electric switches and circuit breakers; collapse of switchyard frames; collapse of overhead gas mains; and interruption of water supply due to electric power loss.[71]

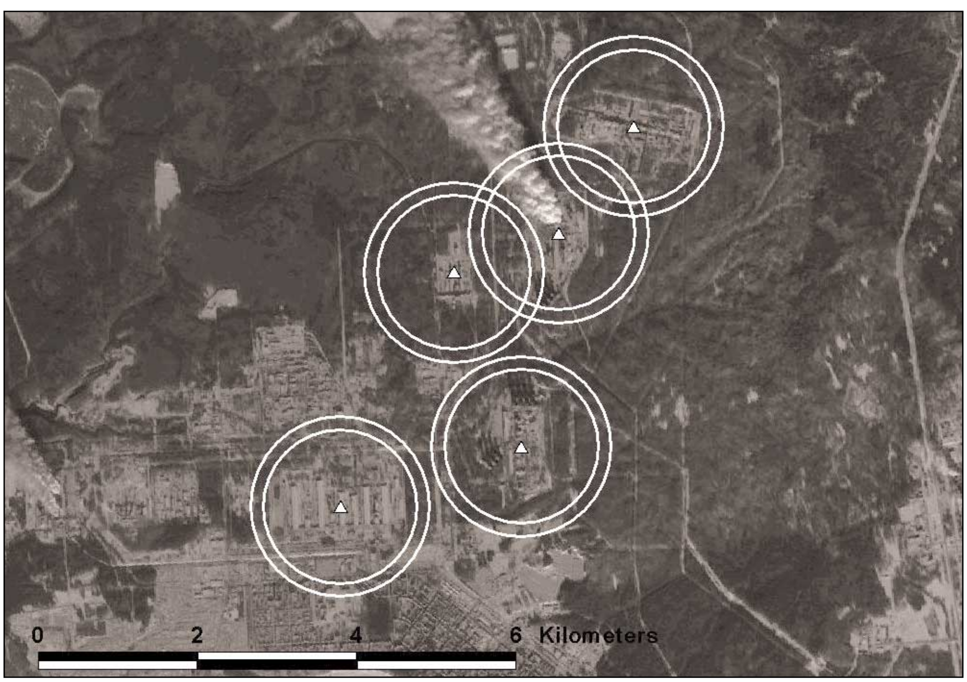


FIGURE 4.72
Seversk
Ikonos satellite image taken on July 10, 2000, and displayed here at 16-meter resolution. Note the plume from the plutonium production reactor. We have targeted the Siberian Chemical Combine. The inner white circles correspond to the severe damage radii and the outer white circles correspond to the moderate damage radii for a 100 kt warhead at a height of burst of 400 meters. Source: spaceimaging.com.

FIGURE 4.73
Angarsk
Ikonos satellite image taken on February 19, 2000, and displayed here at 16-meter resolution. The inner white circle corresponds to the severe damage radius and the outer white circle corresponds to the moderate damage radius for a 100 kt warhead at a height of burst of 400 meters. Source: spaceimaging.com.

We have chosen the 100 kt W76 warhead to attack the key facilities at the eleven cities. The optimum height of burst for a W76 warhead attacking a target with a vulnerability number of 19Q7 is 400 meters. The corresponding severe damage radius is calculated to be 1.05 km, and the moderate damage radius is calculated to be 1.23 km. Figure 4.67 shows a diagram of the Avangard nuclear weapons production plant, one of the two targets near the city of Sarov. Figures 4.68 to 4.73 show the specific choices of targets and damage radii superimposed on 16-meter-resolution satellite images of the Russian nuclear weapons design and production complex that were taken in 2000. Table 4.15 summarizes the targeting information for the Russian nuclear weapons design and production complex.

Casualties and Sensitivity Analysis

With respect to the civilian casualties, a thermal flux of 10 cal/cm^2 (the expected zone of mass fires) would occur at 4.5 km from ground zero, a peak overpressure of 12 psi (where 98 percent of the population are expected to be fatalities in the OTA model) would occur at 1.4 km, a peak overpressure of 5 psi (50 percent fatalities) would occur at 2.4 km, and a peak overpressure of 2 psi (5 percent fatalities) would occur at 4.4 km from ground zero. For a yield of 100 kt and a height of burst of 400 meters, there would be no local fallout. Table 4.16 provides summary casualty and fatality data for the attack on the Russian nuclear warhead design and production complex. We contrast results from the two models for computing casualties (blast versus superfires). Total casualties from the blast model are 350,000 and total fatalities are 147,000. Total fatalities from the superfires model are 371,000.

COMMAND, CONTROL, AND COMMUNICATIONS

Description of Targets

In the actual U.S. SIOP, we assume that degrading communications between the Russian political-military leadership and Russian nuclear forces in the field would be a high priority. Further disruption of Russian command and control of nuclear forces is pursued in MAO-NF by targeting regional nuclear forces headquarters.

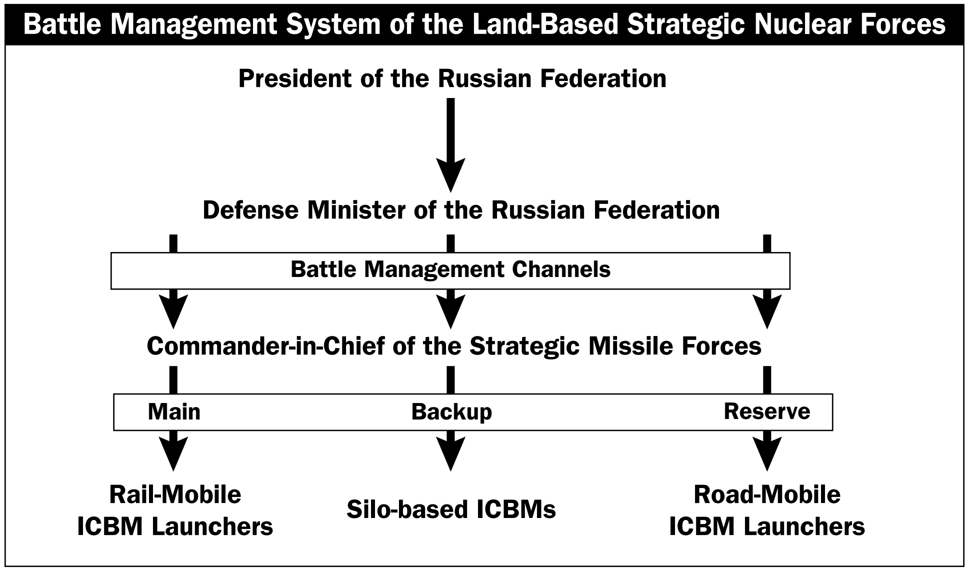
A complete targeting solution for command, control, and communications, or C^3, would include a detailed analysis of how communications flow between the Russian leadership and deployed nuclear forces in a time of crisis. A recent Russian-government publication includes a diagram of the communication pathways between the president and deployed nuclear forces (see Figure 4.74). Below a certain level of command, three parallel paths exist, and evidently serve to provide redundancy in the event of a U.S. attack. Nonetheless, it is likely that destroying a sub-set of all C^3 targets would effectively degrade communications, because a critical sub-set of all C^3 targets probably serves as principal nodes in the system when viewed as a whole. We do not have sufficient data to perform such a nodal analysis. Rather, we have collected open-source information on Russian C^3 assets in order to get a first glimpse at the effects of this component of MAO-NF.

In the NRDC Russian target database, there are currently 362 records for the class of Leadership-C^3 (L-C^3). The categories of targets in this category include (with the number of targets in each category given in parenthesis):

- National government leadership/support (10)
- National-level civilian leadership/support (43)
- National-level military leadership/support (24)
- National-level war support industry leadership (25)
- Intermediate-echelon strategic leadership (13)
- Intermediate-echelon non-strategic nuclear leadership (33)
- Intermediate-echelon non-nuclear leadership (12)
- Intelligence leadership (4)
- Leadership policy, planning and training institutes (2)
- Non-communication electronic installations (21)
- Satellite and space communications (44)
- Telecommunications and electronic warfare (116)

We assume that the categories of intermediate-echelon strategic leadership, non-communication electronic installations (e.g., early-warning radars), satellite and space communications and telecommunications and electronic warfare would be appropriate for MAO-NF, in which there are 194 entries (mapped in Figure 4.75).[75] A selection of targets from some of the other L-C^3 categories would be appropriate for a major attack option specifically directed at national-level leadership in which targeting cities is permitted in the guidance. For example, 87 of the 362 L-C^3 class entries in the NRDC database are located in the city of Moscow and five are located in the city of St. Petersburg.

FIGURE 4.74
Russian Strategic Communication Pathways
Source: *Russia's Arms and Technologies: The XXI Century Encyclopedia*, Volume 1, *Strategic Nuclear Forces* (Moscow, 2000).



Russian satellite systems include the following functional categories: communications[76], navigation[77], meteorology[78], early warning[79], electronic intelligence, photo-reconnaissance, remote sensing, geodesy, radar calibration, space station activity, and scientific activity. A total of 44 geographically distinct satellite earth stations associated with these functions are listed in Table 4.17.

Targeting all satellite earth stations under MAO-NF is probably consistent with the SIOP logic for two reasons. First, about five years have passed since Russia began to commercialize a portion of its telecommunications system. Thus government/military and commercial telecommunications assets are likely still to be

FIGURE 4.75
Intermediate-Echelon Strategic Leadership, Satellite and Space Communications, and Telecommunications and Electronic Warfare Entries in the NRDC Russian Target Database

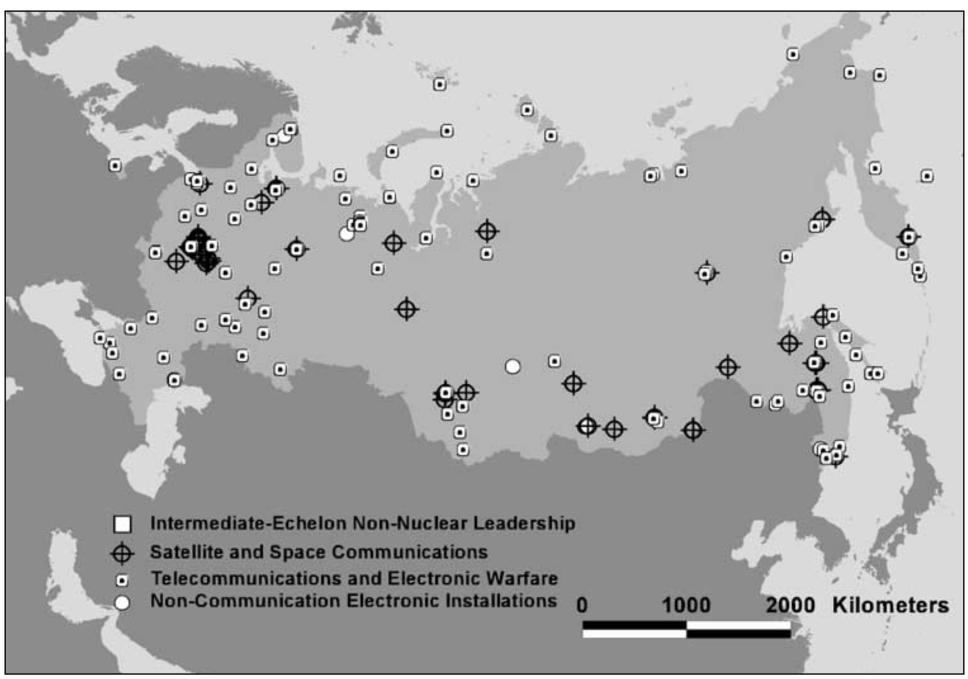
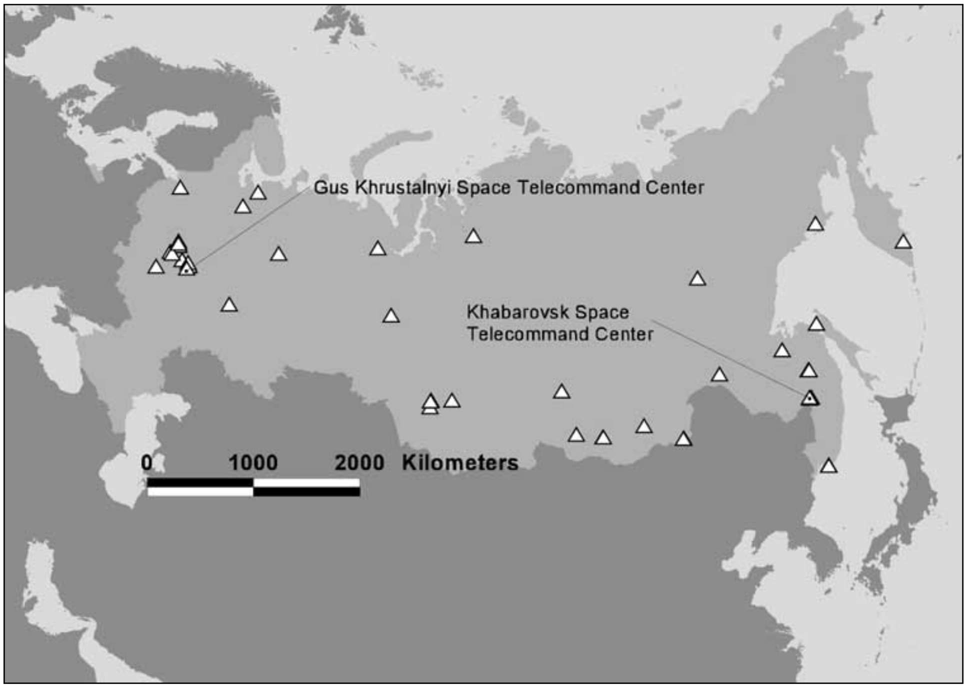


TABLE 4.17
Geographically Distinct Russian Satellite Earth Stations and Their Functions

Station Name	Aeronautical	Fixed-Satellite System	Space Telecommand	Space Research Service	Coast	Space Tracking Station	Meteorological Satellite	Space Telemetering	Earth-Exploration Satellite
ARKHANGHELSK		X							
ARKHANGHELSK	X				X				
DUBNA 1		X							
DUBNA 2,3,4		X							
DUDINKA		X		X		X			
GUS KHRUSTALNY 1,2,3		X							
GUS KHRUSTALNYI		X	X	X					
YAKUTSK		X							
IRKUTSK		X							
KEMEROVO		X							
KHABAROVSK		X	X	X		X	X	X	X
KHABAROVSK		X							
KHABAROVSK 2		X							
KOMSOMOLSKAMUR		X							
KOMSOMOLSKAMUR		X							
KRASNOKAMENSK		X							
MAGADAN		X							
MOSKVA		X					X		
MOSKVA		X		X					
MOSKVA 1		X							X
NAKHODKA	X				X				
NAKHODKA 1		X							
NAUKA		X							
NIKOLAEVSK NA AMURE		X		X					
NIKOLAEVSK NA AMURE1		X							
NOVOSIBIRSK		X							
NOVOSIBIRSK		X							
NOVOSIBIRSK							X		X
PETROPAVLO KAM		X							
PETUSHKI 1,2		X							
S PETERBURG		X							
SALEKHARD		X							
SKOVORODINO		X							
SURGUT		X							
SYKTYVKAR		X							
TAT 1B		X							
TCHITA		X							
TCHITA		X		X		X			
ULAN UDE		X							
VLADIMIR		X							
ZAIARSK		X							

FIGURE 4.76
Russia's Two Space Tele-Command Centers and 45 Earth Satellite Stations



located together. Second, it is also likely that Russia would rely on civilian communication facilities to a certain extent under normal circumstances (as does the U.S.), and as a backup during the crisis that would precede a nuclear exchange. The Russian satellite earth stations and the two space-telecommand centers are mapped in Figure 4.76.

Radio-frequency communication bands are usually divided into categories depending on transmission frequency: extremely low frequency (ELF), very low frequency (VLF), low frequency (LF), medium frequency (MF), high frequency (HF), very high frequency (VHF), ultra-high frequency (UHF), super-high frequency (SHF), extremely high frequency (EHF), and infra-red (IR). Table 4.18 shows the frequency bands commonly associated with these categories, as well as statistics from the International Telecommunications Union database on Russian transmissions.

Given the long propagation range of VLF and LF radio waves, and the ability of VLF waves to penetrate tens of meters into seawater to reach submerged submarines, we plot the location of non-public VLF and LF stations (see Figure 4.77). The figure highlights and labels the five stations that broadcast over all bands, and therefore are likely to be key nodes in the ground-based communications network.

Warhead Requirements and Aimpoints

We do not have a quantitative understanding of vulnerability of these C^3 targets to nuclear weapons effects. It is likely that 100-kt or higher-yield ground bursts would be required to attack the intermediate-echelon leadership targets, and 100-kt air bursts would be sufficient to destroy many of the satellite earth stations and VLF and LF radio-frequency transmitters. In total, we find 175 targets probably suitable to C^3 targeting under MAO-NF.

TABLE 4.18
Electromagnetic Frequency Bands and Statistics for Russian Transmission Stations
The ITU database lists 3,579 geographically distinct Russian radio transmission stations. Range restricted to line of sight is denoted by LOS.

Band Name	ITU Bnd	Frequency Range	Wave Form Name	Propagation	Range (km)	# Stations per Band	# Open to Public
ELF		< 3 KHz					
VLF	4	3-30 KHZ	Myriametric	Surface Wave	10^3–10^4	24	0
LF	5	30-300 KHZ	Kilometric	Surface Wave	10^3–10^4	91	18
MF	6	300-3000 KHZ	Hectometric	Sky Wave		603	194
HF	7	3-30 MHZ	Decametric	Sky Wave		1069	842
VHF	8	30-300 MHZ	Metric	Direct Wave	LOS	2276	29
UHF	9	300-3000 MHZ	Decimetric	Direct Wave, Scatter	LOS	788	23
SHF	10	3-30 GHZ	Centimetric	Direct Wave, Scatter	LOS	33	2
EHF	11	30-300 GHZ	Millimetric	Direct Wave	LOS	3	0
(IR)	12	300-3000 GHZ	Deci-millimetric				

Casualties and Sensitivity Analysis

While we do not have sufficient information to perform a detailed targeting analysis for this component of Russian nuclear forces, our database does reveal how many of these targets occur in major urban areas, and thus would be withheld under guidance that precludes attacking Russian cities. Figure 4.78 is a histogram plot of the number of potential C^3 targets for which the given range of people live within a

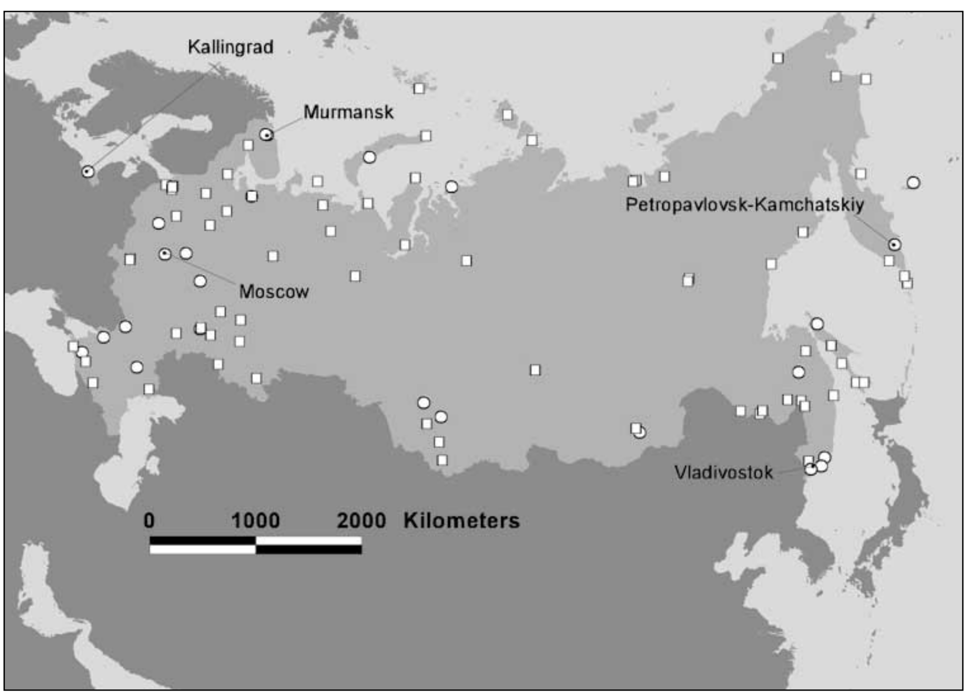
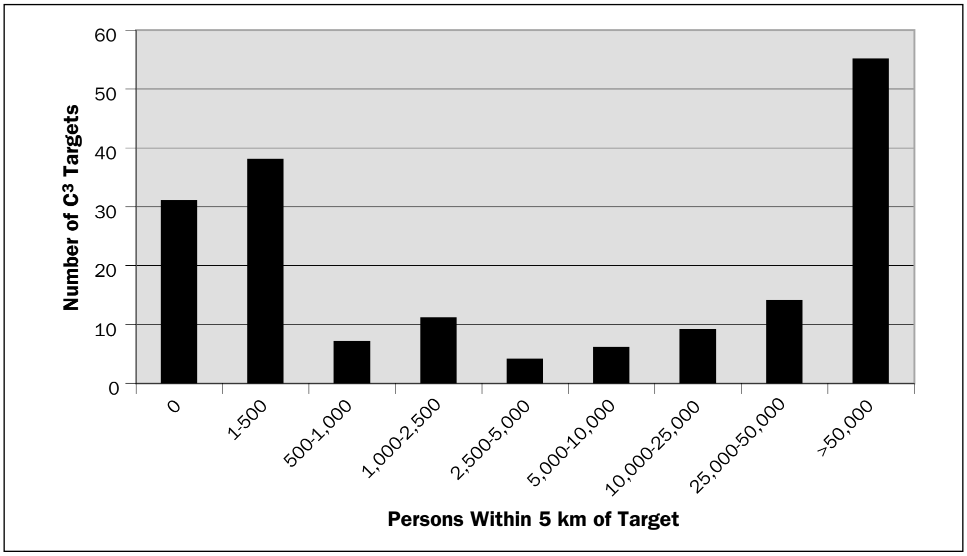


Figure 4.77
Russian Radio Transmission Stations
VLF (circle) and LF (square) non-public radio transmission stations. Five stations, which transmit in all bands, are labeled.

FIGURE 4.78
Histogram of the Number of Potential C^3 Targets for which the Given Range of People Live within a 5-kilometer Radius

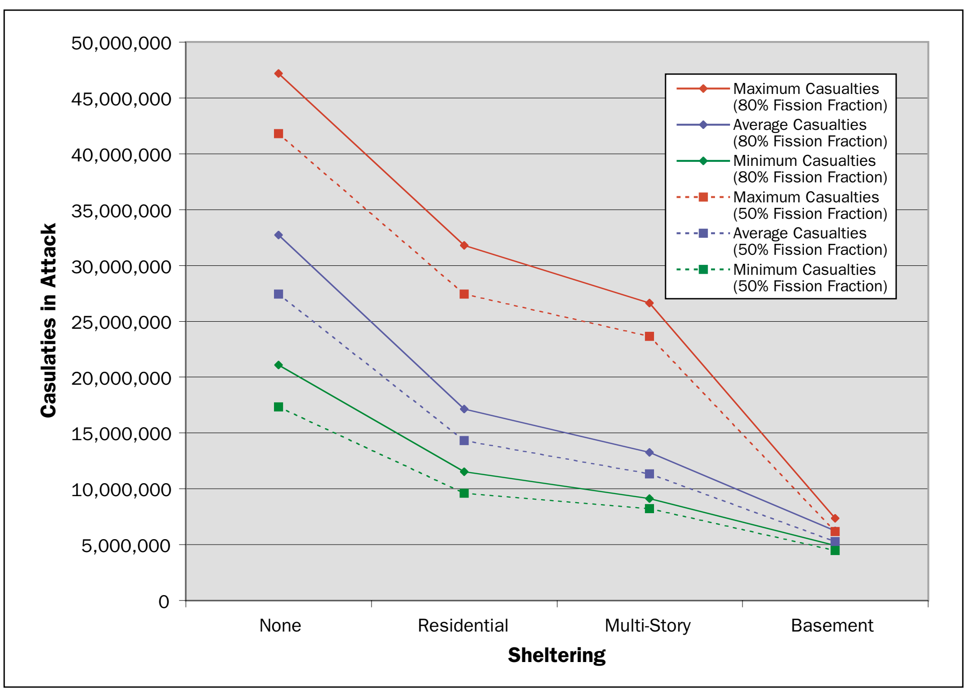


5-km radius (the outer radius for prompt effects of a W76). If the withhold against attacking cities in the guidance can be interpreted as a withhold on attacks for which there are more than 10,000 persons within a 5-km radius, then 97 of the C^3 targets could still be attacked, potentially threatening 86,000 people.

CONCLUSION

We have considered in detail the U.S. warhead requirements and Russian casualties for an attack against Russian nuclear forces. Drawing on the most comprehensive

FIGURE 4.79
Summary Casualty Data for MAO-NF



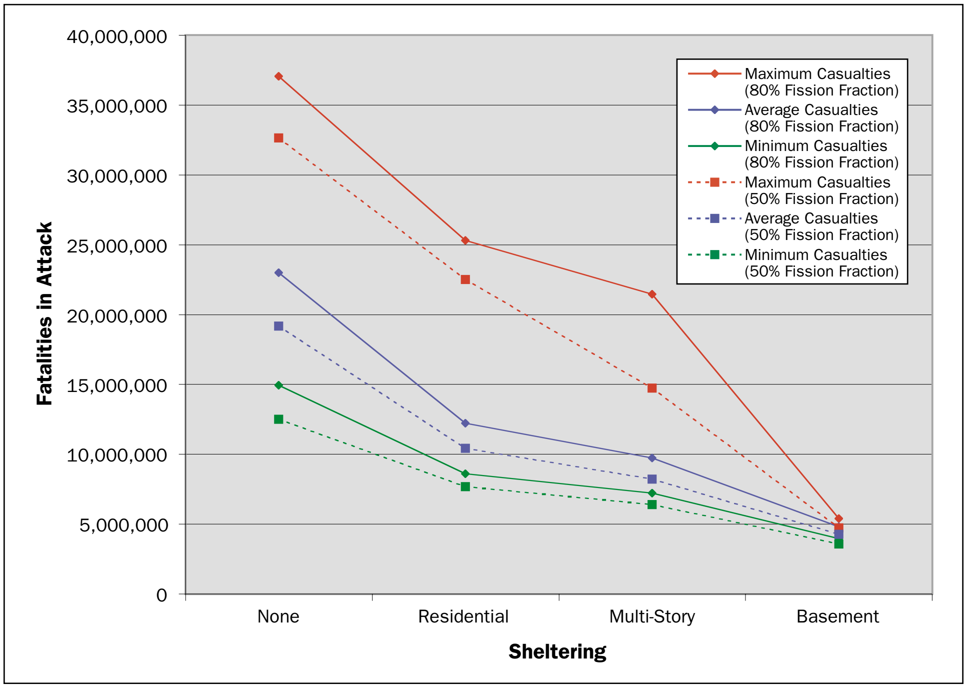


FIGURE 4.80
Summary Fatality Data for MAO-NF

levels of targeting for Russian aviation and naval sites, the total number of warheads used was 1,289, including:

- ▶ 500 W87 warheads, representing all of the single-warhead MM III ICBMs
- ▶ 220 W88 warheads, representing half of all W88 warheads, or the equivalent of 1.1 fully-loaded SSBNs
- ▶ 569 W76 warheads, the equivalent of three fully-loaded SSBNs

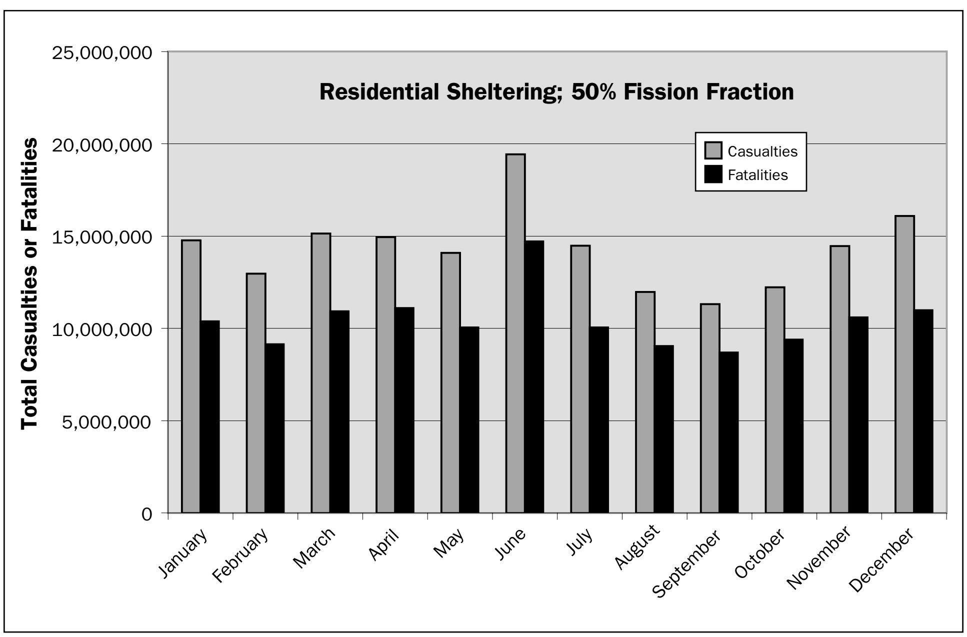
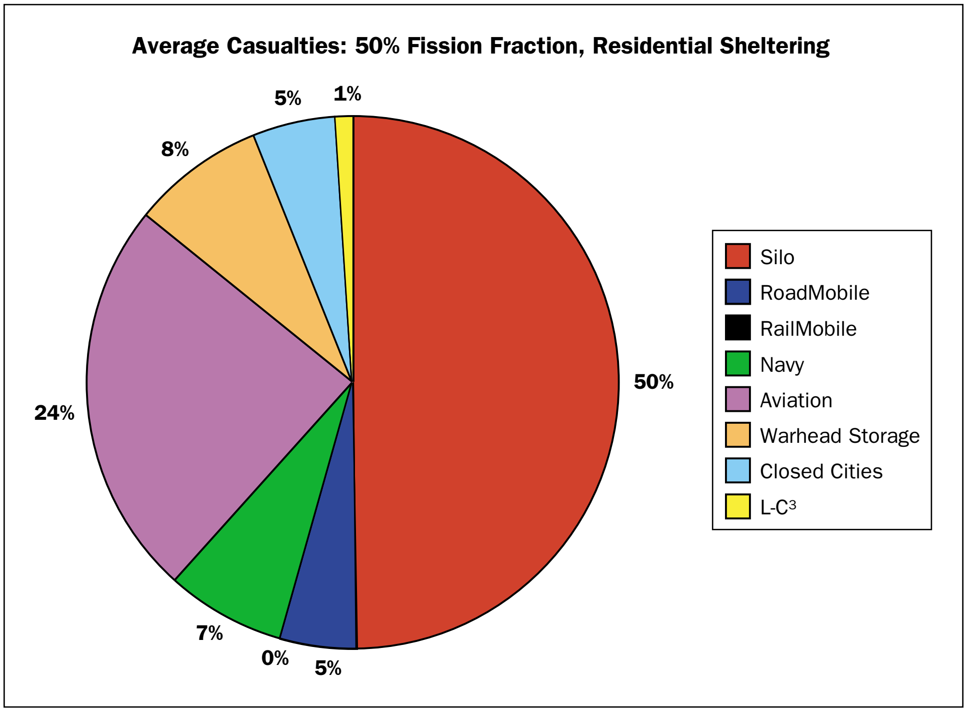


FIGURE 4.81
MAO-NF Casualties and Fatalities as a Function of Month of the Year
Assuming a weapon fission fraction of 80% and a population sheltering corresponding to residential dwellings.

FIGURE 4.82
MAO-NF Casualties Separately Evaluated for the Eight Components of Russia's Nuclear Forces



This works out to be almost one half the number of U.S. nuclear weapons on high alert today and essentially all of the weapons on high alert in a future START II force.

The attack, which would last a total of 30 minutes, would result in the following:

- More than 90 percent of Russian ICBM silos would be severely damaged
- All fifty SS-25 garrisons and bases would be destroyed
- All three SS-24 bases would be devastated by air bursts
- All Russian Northern and Pacific Fleet naval sites would be radioactive ruins, and any SSBNs that had been in port would become blasted pieces of metal on the bottom of the bays
- More than 60 important air fields would have their runways cratered and any strategic bombers caught at the air bases would be severely damaged
- Seventeen nuclear warhead storage sites would have their 136 bunkers turned into radiating holes
- The entire Russian weapons production and design complex would be blasted apart, killing in the process a large fraction of the nuclear workers
- Communications across the country would have been severely degraded

Within hours after the attack, the radioactive fallout would descend and accumulate, creating lethal conditions over a land mass with an area exceeding 775,000 square kilometers—larger in size than France and the United Kingdom combined. The key to survival in the first two days after the attack would be staying indoors, preferably in the upper stories of high-rise apartment buildings or in basements. Figure 4.79 plots the casualties and Figure 4.80 plots the fatalities for

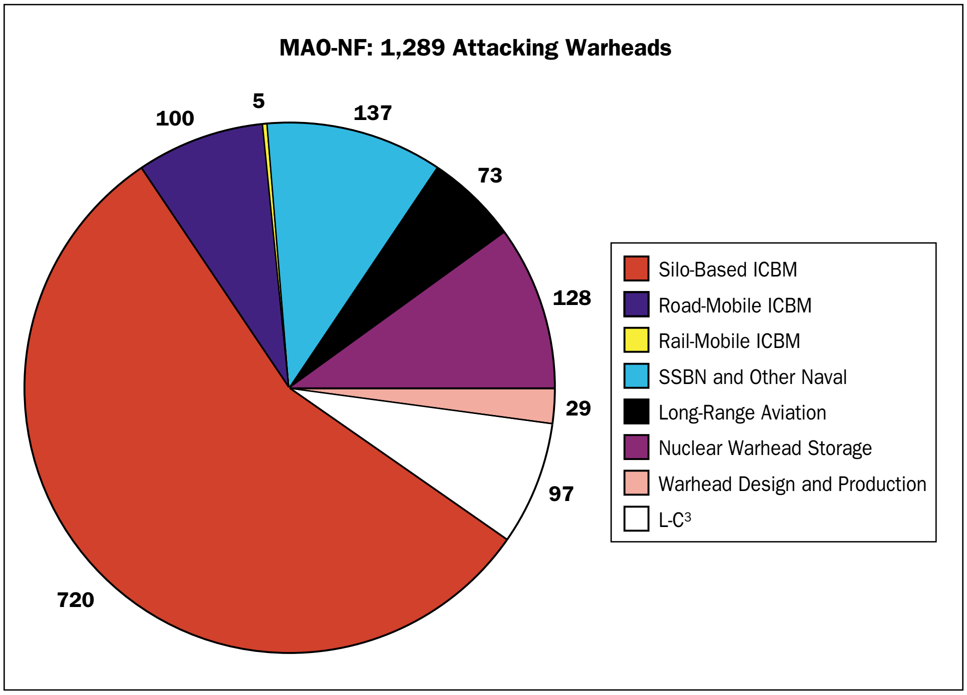
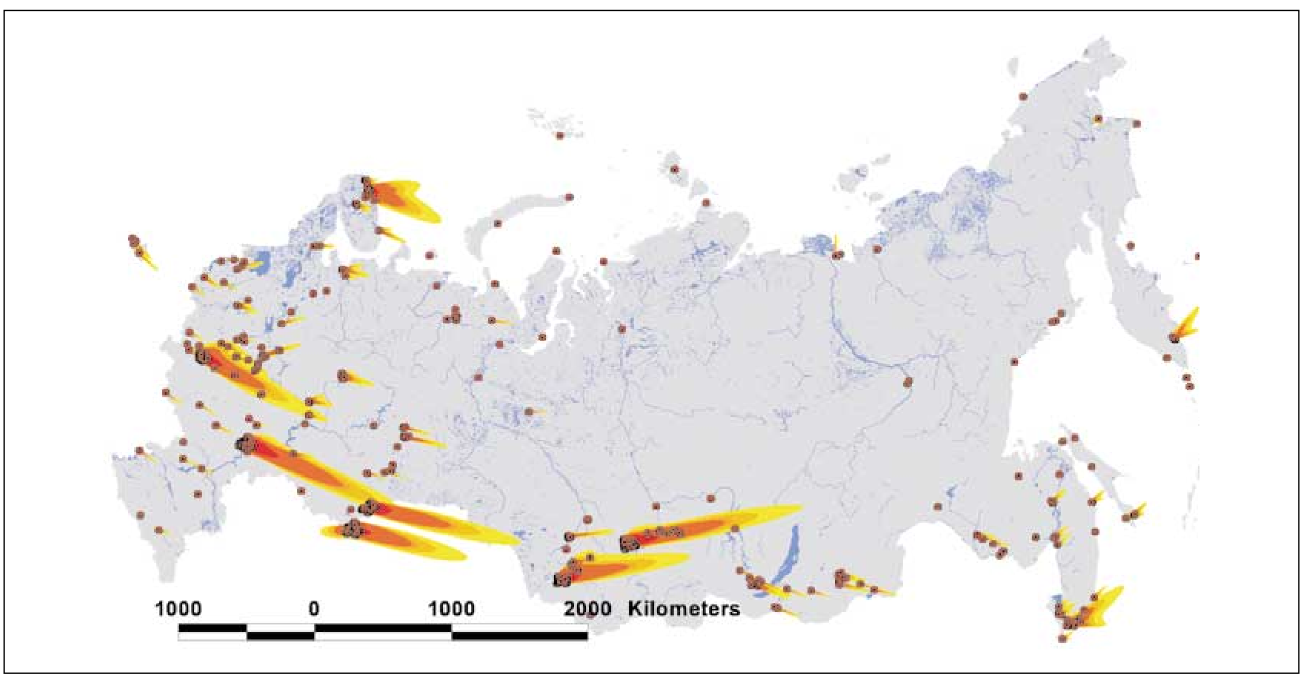


FIGURE 4.83
The Allocation of U.S. Warheads to the Eight Categories of Russian Targets in NRDC's MAO-NF

MAO-NF as a function of population sheltering. Figure 4.81 plots the casualties and fatalities as a function of month for an assumption of 80 percent fission fraction and a population sheltered in residential (single-story) dwellings. Figure 4.82 shows how the casualties in MAO-NF rank among the eight categories of targets we have considered in this study. Figure 4.83, to be contrasted with Figure 4.82, illustrates how NRDC allocated attacking U.S. nuclear weapons to the eight components of

FIGURE 4.84
Fallout Patterns from MAO-NF Across the Russian Landmass ▼



Russia's nuclear force under MAO-NF. Finally, Figure 4.84 displays the fallout patterns across Russia for MAO-NF.

Considering the monthly variation in wind parameters, the likely bounding values of 50 percent and 80 percent fission fraction, and the likely bounding values of residential and multi-story sheltering, we find that the casualties resulting from MAO-NF would be between 11 and 17 million people, including between 8 and 12 million fatalities.

CHAPTER FIVE

Attacking Russian Cities: Two Countervalue Scenarios

The nuclear dangers that the United States and Russia survived during the Cold War have persisted into the twenty-first century. Both countries continue to affirm the importance of nuclear weapons to their national security and currently retain over 14,000 strategic warheads in their combined arsenals. The United States government remains convinced that nuclear weapons serve as useful tools in the conduct of foreign policy. Our government claims that they can and should play a variety of roles beyond deterring the use of nuclear weapons, such as deterring or responding to conventional, chemical, or biological attacks, as well as shielding allies around the globe. We find that, rather than enhancing security, these extended roles in fact undermine it, and contradict the attainment of the nation's most important security goal, which is to lessen the threat of nuclear attack and prevent the spread of nuclear weapons to hostile states or groups. Abandoning these illusory roles can—along with dropping the major attack option—lead to a significantly smaller arsenal. In this chapter we take a fresh look at that fundamental question: "How much is enough?" or more specifically, "How many nuclear weapons are necessary for deterring a nuclear attack on the United States, which is arguably the only reason for continuing to possess them at all?"

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At times during the Cold War, the U.S. definition of deterrence included our ability to destroy at least 25 percent of Soviet citizenry. The Major Attack Option we presented in Chapter Four did not try to accomplish this, because it targeted nuclear forces, not population centers. The two scenarios we present below demonstrate that deterrence, defined in this way, can be reached with remarkably few warheads. Before presenting our calculations, we briefly review population targeting in U.S. nuclear policy—revisiting the Cold War planning assumptions and judgments about the need and ability to destroy urban-industrial areas.

"ASSURED DESTRUCTION": TARGETING POPULATION CENTERS

Nuclear warheads have long been targeted not just at military forces, but at population centers as well. Indeed, from the end of World War II until well into the Cold

War, the primary purpose of nuclear weapons was to destroy an entire city with just one or two weapons. During the war in Europe and the Pacific, area bombing of cities with high-explosive and incendiary bombs intensified, becoming commonplace and an accepted strategy in the conduct of war. The bombing of Dresden on February 13–15, 1945, resulted in 135,000 deaths and that of Tokyo on March 9–10, 1945 caused 83,000 deaths. According to an authority on the history of the SIOP, "The same factors that contributed to the emphasis on urban/industrial targeting in World War II continued to be factors in the early nuclear era."[1] The military, and particularly the U.S. Air Force, believed that atomic bombs could do the job better than conventional bombs. In August 1945 the atomic bombings of the Japanese cities of Hiroshima and Nagasaki resulted in over 210,000 deaths by the end of the year using only two bombs.

Early U.S. nuclear war plans involved only the bombing of cities: the 1948 war plan FLEETWOOD "called for the use of 133 bombs in a single massive attack against 70 Soviet cities." War plan TROJAN "provided for a total of 300 atomic bombs to be dropped on Russia and included the all-out bombing of Soviet cities and industry." As we have seen in Chapter Two, the first SIOP, created late in the Eisenhower administration, called for "attacks on all major Soviet and other Communist cities in the event of war. In some cases ten bombs were targeted on a single city. In the event of war, 360 to 525 million casualties were predicted."[2]

In a November 21, 1962 memo to President Kennedy, Secretary of Defense McNamara provided a justification for his proposed strategic nuclear force acquisitions and sought to quantify the destruction sufficient to deter a nuclear attack on the United States by the Soviet Union:

> *It is generally agreed that a vital first objective, to be met in full by our strategic nuclear forces, is the capability for assured destruction. Such a capability would, with a high degree of confidence, ensure that we could deter under all foreseeable conditions, a calculated, deliberate nuclear attack upon the United States. What amounts and kinds of destruction we would have to be able to deliver in order to provide this assurance cannot be answered precisely, but it seems reasonable to assume that the destruction of, say, 25 percent of its population (55 million people) and more than two-thirds of its industrial capacity would mean the destruction of the Soviet Union as a national society. Such a level of destruction would certainly represent intolerable punishment to any industrialized nation and thus should serve as an effective deterrent. Once an assured destruction capability has been provided, any further increase in the strategic offensive forces must be justified on the basis of its contribution to limiting damage to ourselves.*

McNamara's analysis was presented in the famous mutually assured destruction (MAD) curve, demonstrating a point of diminishing returns, or a "knee," in an attack of Soviet urban-industrial targets at 400 equivalent megatons. The equivalent megatonnage of a nuclear weapon is expressed by $Y^{2/3}$, where Y is the yield of the weapon measured in kilotons or megatons. Equivalent megatonnage is roughly proportional to the area under a nuclear blast receiving a given peak overpressure. In other words, using the measure of equivalent megatonnage, a 1,000 kiloton (or 1 megaton) weapon does not destroy by blast ten times the area of a 100 kt weapon, but rather only about 4.6 times as much (i.e., $1{,}000^{2/3}/100^{2/3}$).

McNamara's calculation of damage to Soviet urban/industrial targets as measured in equivalent megatons is given in Table 5.1. The reverse calculation, where the Soviet forces attack U.S. urban/industrial targets is given in Table 5.2. In the early 1960s, before there were MIRVed missiles, the average yield of a U.S. ICBM warhead was approximately one megaton, which in Table 5.1 corresponds to an equal number of weapons. In discussing the table, McNamara stated:

> *The point to be noted from this table is that 400 one megaton warheads delivered on Soviet cities, so as to maximize fatalities, would destroy 40 percent of the urban population and nearly 30 percent of the population of the entire nation. . . . If the number of delivered warheads were doubled, to 800, the proportion of the total population destroyed would be increased by only about ten percentage points, and the industrial capacity destroyed by only three percentage points. . . . This is so because we would have to bring under attack smaller and smaller cities, each requiring one delivered warhead. In fact, when we go beyond about 850 delivered warheads, we are attacking cities of less than 20,000 population.*

Therefore relatively few weapons inflicted "assured destruction"—what McNamara viewed as the core of the U.S. deterrent strategy.

A decade after McNamara, U.S. military war planners developed more refined analytical techniques to quickly calculate the fraction of a city's population that would be killed by a given number of nuclear weapons having the same yield, accuracy, and reliability. This shorthand method became known as the "Q and A parameters" (see Box, page 117). Population densities for attacked cities were assembled into P-95 circles for use in countervalue calculations.[3] Most likely, a lack of computing power at the time motivated the development of the Q and A

TABLE 5.1
McNamara's "Assured Destruction" Calculations for a U.S. Attack on Soviet Urban/Industrial Targets
In McNamara's words: "The destructive potential of various size U.S. attacks on Soviet cities is shown in the following table, assuming both the existing fallout protection in the Soviet Union, which we believe to be minimal, and a new Soviet nation-wide fallout shelter program."[4] In this table "mil." denotes millions and "Ind. Cp." denotes industrial capacity.

	Limited Urban Fallout Protection				Nation-Wide Fallout Program				
Delivered Megatons/ Warheads	**Urban (mil.)**	**Urban (%)**	**Total (mil.)**	**Total (%)**	**Urban (mil.)**	**Urban (%)**	**Total (mil.)**	**Total (%)**	**Ind. Cp. (%)**
100	20	15	25	11	16	12	17	7	50
200	40	29	46	19	30	21	32	13	65
400	57	41	68	28	48	35	51	21	74
800	77	56	94	39	71	52	74	31	77
1200	90	65	109	45	84	61	87	36	79
1600	97	70	118	49	92	67	95	39	80

parameters. The goal of the Q and A technique was to routinely and efficiently allocate thermonuclear warheads in order to kill a specified fraction of civilians in urban areas. That the P-95 population data format was until recently in use by U.S. nuclear war planners can be seen in a 1999 USSTRATCOM briefing where the nomenclature "P-95 circles" and "rural cells" are used to analyze Algeria's population. Another view-graph from this briefing states that a P-95 circle: "[is] Used in urban areas of 25,000 people or more; [is a] 0.5–7 nautical mile radius circle containing 95 percent of population within; [and] Contains a minimum of 2500 people;" and rural cells are defined as "20′ by 30′ gridded cells containing rural population."[5]

The goal of the Q and A technique was to routinely and efficiently allocate thermonuclear warheads in order to kill a specified fraction of civilians in urban areas.

In 1979, fifteen years after Robert McNamara publicly presented his MAD curve to Congress, Science Applications, a Pentagon contractor, wrote a classified report for the Defense Nuclear Agency entitled, *The Feasibility of Population Targeting*.[6] In the introduction the authors wrote:

> *The cornerstone of current U.S. strategic doctrine is deterrence of nuclear war through maintenance of an assured destruction capability. In practical terms, this requires that we maintain the capability to absorb a first strike by the enemy and retaliate with an unacceptable level of damage on the Soviet Union. . . . The Secretary of Defense's Annual Report for Fiscal Year 1979 expresses the assured destruction task as follows: "It is essential that we retain the capability at all times to inflict an unacceptable level of damage on the Soviet Union, including destruction of a minimum of 200 major Soviet cities."*[7]

The Science Applications report provides an extensive mathematical analysis of how to kill millions of people in a nuclear war, and even takes into account the influence of the Soviet civil defense program. The report argues that if population targeting is a goal, then the U.S. war plan should target those who are evacuated.

> *[I]f this concept [of population targeting] is to be pursued in the face of evacuation, i.e., if evacuated people are to be located and targeted, there are significant implications for command, control, communications and intelligence (C3I), the possible degradation of damage expectancy (DE) against urban industrial targets (if weapons initially assigned to them are*

TABLE 5.2
McNamara's "Assured Destruction" Calculations for a Soviet Attack on U.S. Urban/Industrial Targets
In McNamara's words: "The yield of each warhead is assumed to be 10 Mt. As in the case of the counterpart table (i.e., Table 5.1, above), U.S. fatalities are calculated under conditions of a limited, as well as a full, nation-wide fallout shelter program."[8] In this table "mil." denotes millions and "Ind. Cp." denotes industrial capacity.

	Limited Fallout Protection				Nation-Wide Fallout Program				
Delivered Warheads (10 MT)	Urban (mil.)	Urban (%)	Total (mil.)	Total (%)	Urban (mil.)	Urban (%)	Total (mil.)	Total (%)	Ind. Cp. (%)
100	79	53	88	42	49	33	53	25	39
200	93	62	116	55	64	43	74	35	50
400	110	73	143	68	80	53	95	45	61
800	121	81	164	78	90	60	118	56	71

> *retargeted against evacuated people), and the impact upon weapons requirements that could result after tradeoffs in urban-industrial DE and fatality levels have been considered.*[9]

Using U.S. intelligence information, the report claimed that the Soviet Union had established evacuation procedures calling for a buffer zone around each major city. The zone was ring shaped: "8 nautical miles (14.8 kilometers) in thickness whose inner boundary is located along the periphery of the city proper. It is intended to ensure that people evacuated beyond this zone will not be subjected to more than 1.4 psi (0.1 kg/cm^2) from yields of a megaton or less detonating along the city periphery."[10] Thus 1.4 psi was considered by the Soviets as the blast overpressure threshold for an

Q and A Parameters for Population Attacks

Taken from *The Feasibility of Population Targeting*

"A total of 1532 USSR population centers representing a projected 1981 population of 144 million people were depicted by 10 city classes. Each city was defined by a number of population centers (P-95's) that varied from 1 to 92 in number, depending upon the size of the individual city. Radii of these P-95's varied from 0.25 to 1.0 nautical miles (nm), and the distribution of population within the P-95 was assumed to be circular normal. Weapons were allocated against this database so as to maximize the effectiveness of each successive weapon considering the damage expectancy of all preceding weapons. The results of these hypothetical attacks provided the necessary data which, when subjected to curve-fitting and other analytical techniques, yielded two parameters, Q and A, for each combination of weapon yield, accuracy, and reliability.

"These parameters were used in the formula: $D_i(n) = 1 - Q_i^{n^A}$, where D_i is the fraction of population of city class i killed by n weapons of the type for which the Q/A parameters were calculated. Q_i is equal to one minus the single-shot kill probability (1-SSPK) of a single weapon, and A is a factor which modifies the exponent n to account for the nonuniform distribution of population and the overlapping coverage of successive weapons. In effect, the formula is a variation of the expression: $DE_{CUM} = 1 - \left[(1 - DE_1)(1 - DE_2)\ldots(1 - DE_n)\right]$, which is used to calculate the cumulative damage expectancy (DE_{CUM}) to a single target resulting from the application of several different (n) weapons. The Q/A formula simply uses a modified version of this basic expression to represent the cumulative damage to the several P-95's of a given city from n weapons having identical characteristics . . .

"Several important assumptions were embodied in the original development of the original Q/A approach. First, the entire population was assumed to be located in multistory concrete buildings and in an unwarned nighttime posture. The weapons height of burst was optimized for the multistory structure. Next, the fatality calculations considered only blast and prompt radiation effects. Finally, the aimpoint of the nth weapon was optimized given the fatalities expected from the preceding n-1 weapons . . .

"Despite the limitations described above, there are several very attractive features in the technique. In addition to the fact that the basic procedure is already in being, the computer resources required are minimal, thus permitting a large number of attack alternatives to be analyzed economically. Further, the database contains a large portion of the Soviet population."[11]

urban population at risk. The report concluded, apparently using the McNamara criteria of 25 percent casualties as an adequate measure for deterrence, that of an estimated Soviet population of 246 million at the time, 60 million casualties would, in their language "develop adequately the relationship between weapons requirements and fatalities as a function of various levels of shelter and evacuation."[12]

It is worth underscoring the fact that targeting major Soviet cities, as articulated by McNamara in the early 1960s, persisted for twenty years into the Reagan administration as a core component of the concept of deterrence.

TWO COUNTERVALUE SCENARIOS

NRDC does not have any information about the role of countervalue targeting in the current SIOP, but what we do know about U.S. nuclear war planning emphasizes historical continuity. In this section, we evaluate the consequences of two scenarios in which small pieces of the current U.S. nuclear arsenal attack Russian cities and exceed the goals articulated by McNamara. This exercise demonstrates the destructive power of very few nuclear weapons, using nuclear deployments that are plausible if the United States reduces its forces to such low levels: one silo field of single-warhead MM III ICBMs or one fully-laden Trident SSBN.

Russia is currently comprised of 89 regions with an area of 16.9 million square kilometers and a population of 152 million[13], making it about twice as big as the United States with half the population. The Ural Mountains split Russia into a "European" portion that contains most of the people while an "Asiatic" portion includes most of the land mass. The 53 Russian regions west of the Urals have about three quarters (102 million) of the population. According to the last Soviet census conducted in 1989, 22 of the 34 Soviet cities with a population over 500,000 were located in European Russia, including Moscow (8.8 million) and St. Petersburg (5 million).

FIGURE 5.1
A Trident II SLBM Being Launched

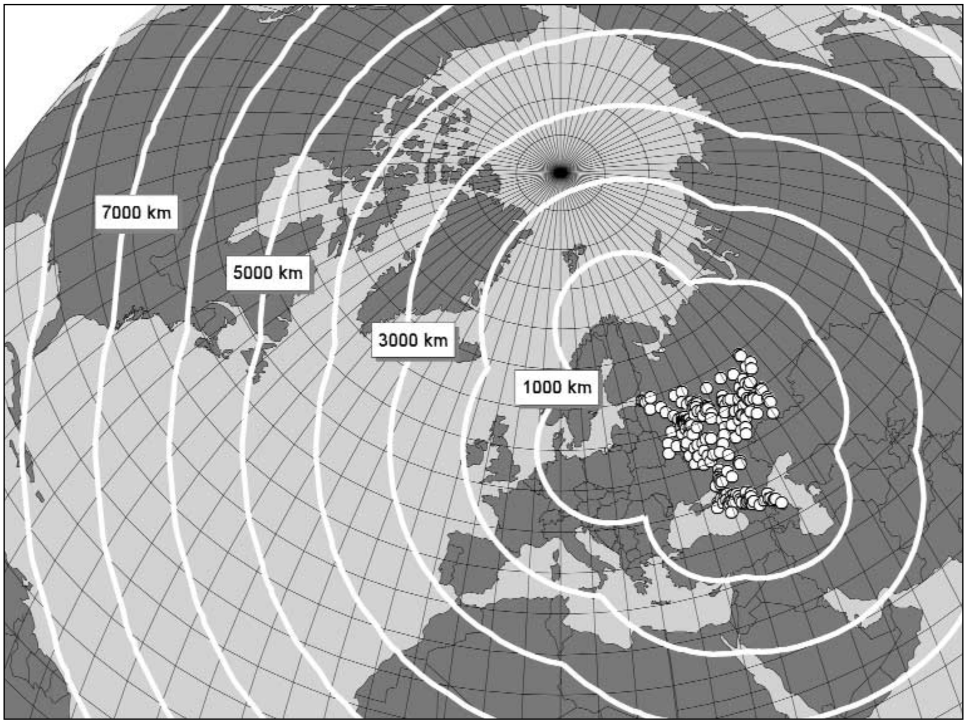


FIGURE 5.2
A Map Showing the 192 Targets in European Russia for the Trident Scenario and Buffered Distances

To target these various population centers, our two scenarios utilize America's premiere strategic weapons: Trident II and Minuteman III. These long-range ballistic missile systems were designed during the Cold War to meet specific military requirements to destroy hardened targets such as Soviet ICBM silos and underground command bunkers. Our scenarios explore the capabilities of Trident and Minuteman III against "soft" targets—Russian cities. We demonstrate that ballistic missiles designed for use in a first strike, or prompt counterforce, can be employed as a retaliatory weapon, or as part of a "strategic reserve,"

TABLE 5.3
Trident and Minuteman III Weapon System Parameters for the Two NRDC Countervalue Scenarios
Sources: U.S. Congress, *Trident II Missiles: Capability, Costs, and Alternatives* (Washington, DC: Congressional Budget Office, July 1986); John M. Collins and Dianne E. Rennack, *U.S. Armed Forces Statistical Trends, 1985–1990 (As of January 1, 1991)* (Congressional Research Service, The Library of Congress, September 6, 1991), Tables 5 and 6.

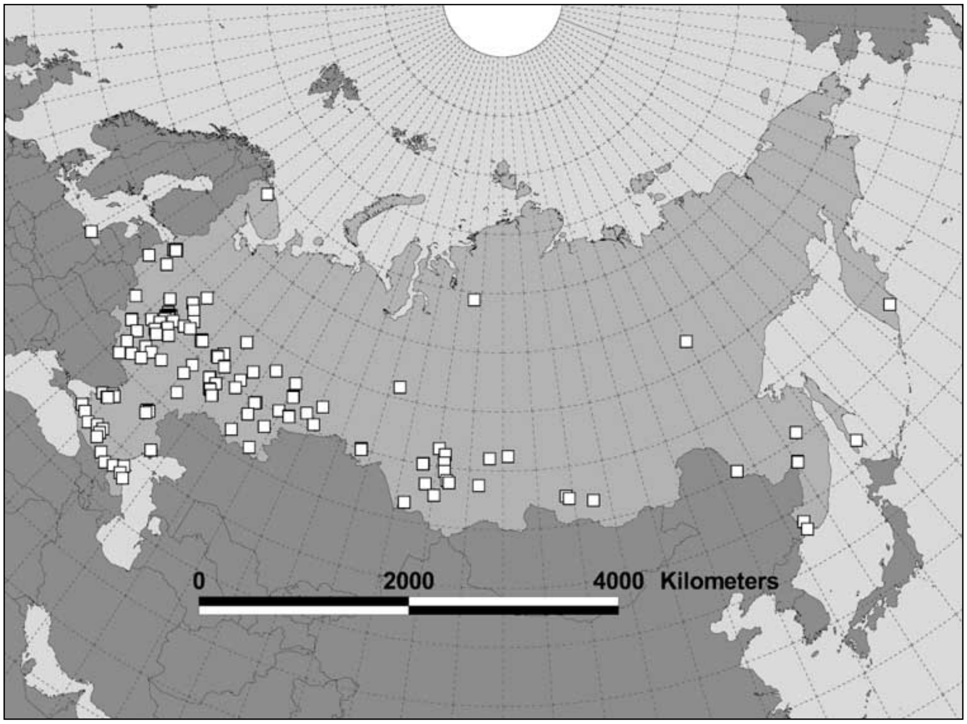
NRDC Scenario and Weapon System	Total Number of Missiles	Warhead MIRV, Yield and Type	Total Number Warheads and Total Yield	Range (km)	Accuracy (meters)	Reliability (%)
Scenario 1: Trident II D-5	24 (one deployed submarine)	8, 475 kt W88 warheads per missile	192 warheads and 91,200 kt	7,400 (at full payload)	125	80%
Scenario 2: Minuteman III	150 (all ICBMs at Minot Air Force Base, North Dakota)	1, 300 kt W87 warhead per missile	150 warheads and 45,000 kt	> 13,000 km[a]	≤225[b]	80%[c]

[a] The range is for the three warhead Minuteman III. The range of a single warhead Minuteman III would be greater since the payload is lighter.

[b] For the three warhead Minuteman III using the Mk-12A RV.

[c] We assume the reliability figures of the Minuteman III are similar to the published values for the Trident II.

FIGURE 5.3
A Map Showing the 150 Aimpoints Throughout Russia for the Minuteman III Scenario

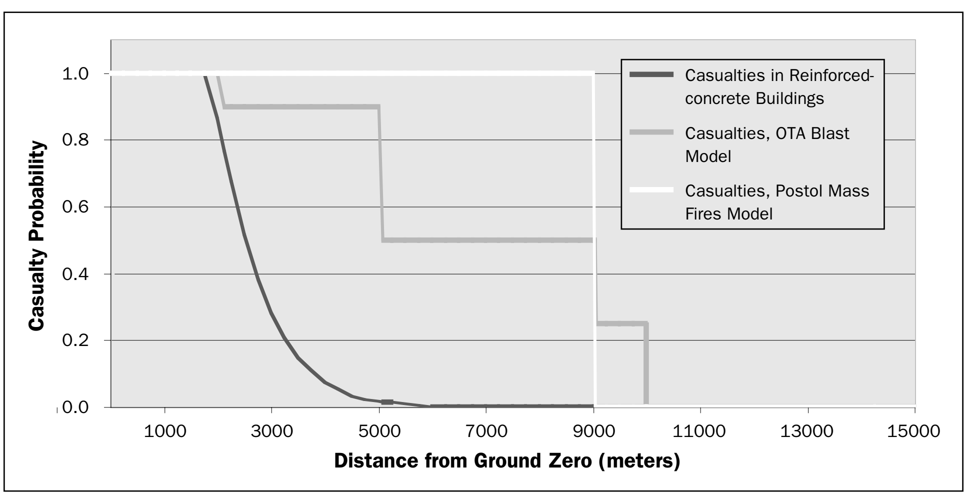


intended to hold Russia's urban citizens at risk.[14] For instance, the more populous western portion of Russia can be threatened by Trident SSBNs on patrol in the mid-Atlantic at points roughly north of New York City and east of Greenland. Minuteman III ICBMs can threaten all of Russia from their silos in the western United States. The conclusions of our exercise illustrate how few of these weapons we need for deterrence.

The First Countervalue Attack Scenario

Our first scenario involves an attack by the full complement of missiles aboard one Trident submarine. Currently, U.S. Trident SLBMs are deployed in three configura-

FIGURE 5.4
Probability of Being a Casualty as a Function of Distance from Ground Zero
For a 475-kt W88 air burst (at 2 km height of burst) for three models: casualties in severely and moderately damaged; reinforced concrete buildings; casualties as would be predicted from the OTA blast model; and casualties as would be predicted from Postol's mass fires model.



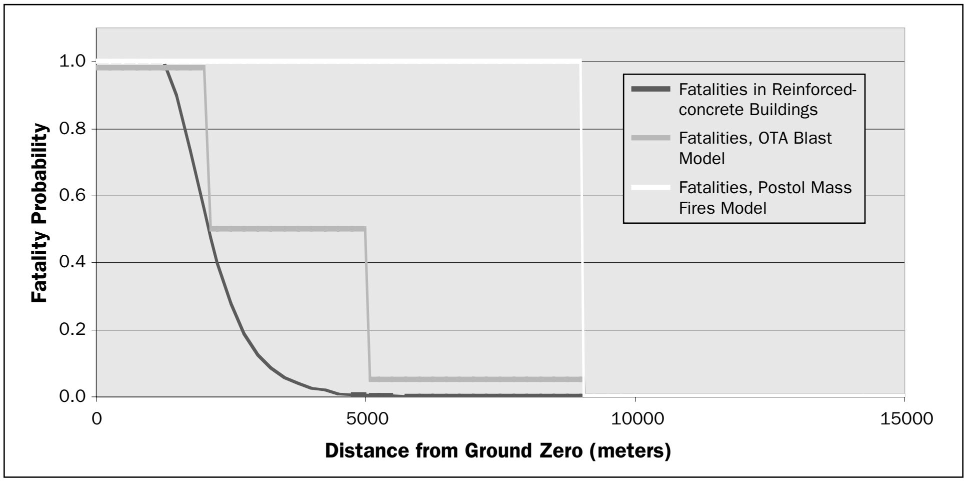


FIGURE 5.5
Probability of Being a Fatality as a Function of Distance from Ground Zero
For a 475-kt W88 air burst (at 2 km height of burst) for three models: fatalities in severely and moderately damaged; reinforced concrete buildings; fatalities as would be predicted from the OTA blast model; and fatalities as would be predicted from Postol's mass fires model.

tions: Trident I C-4 SLBMs armed with up to eight W76 (100-kiloton) warheads; Trident II D-5 SLBMs armed with up to eight W76 warheads; and Trident II SLBMs armed with up to eight W88 (475-kiloton) warheads. By 1990 or 1991, the United States had produced only about 400 W88 warheads. The government had planned initially to produce many more, but production was cut short when the government shut down several key nuclear weapons production plants, beginning with the Rocky Flats Plant in Colorado where plutonium pits were produced. The existing 400 warheads are enough for two Trident submarines with a full complement of 24, 8-warhead MIRVed SLBMs. Our scenario assumes one fully loaded SSBN carrying only W88 warheads, a plausible future deployment.

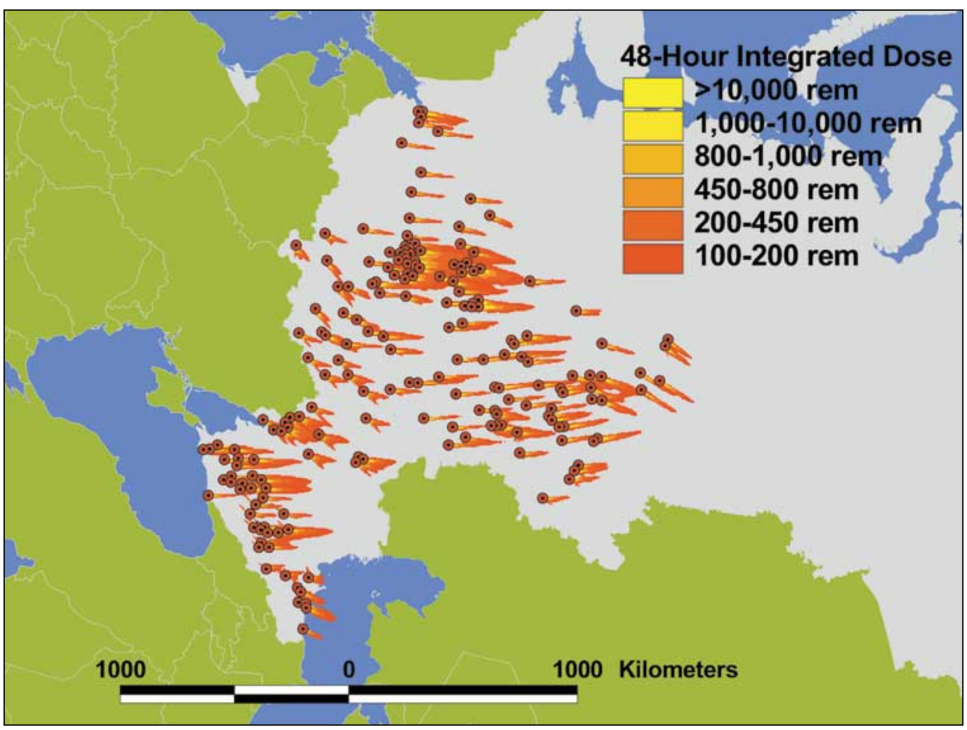


FIGURE 5.6
Fallout Patterns for the Trident Scenario with Ground Bursts

Second Countervalue Attack Scenario

In the second countervalue scenario, we show the results of an attack by the 150 single-warhead Minuteman III ICBMs based at Minot Air Force Base in North Dakota. Under START II all MIRVed ICBMs would be banned. The Air Force is replacing the propulsion and guidance systems for Minuteman III ICBMs so that they will last at least until 2020, at a total cost of $5 billion, including $1.9 billion for the new ICBM guidance system (the NS-50 guidance system).[15] At the same time, the three-warhead configuration for the Minuteman III, with W78 and W62 warheads, is scheduled to be replaced by a single-warhead configuration using the Peacekeeper (W87) warhead. Our scenario uses the Minuteman with the 300-kt W87 warhead, a plausible future strategic deployment.

TABLE 5.4
Vulnerability Numbers and Damage Radii for Various Building Types
Damage radii are computed for W87 and W88 air bursts (at a height of burst of 1,800 meters and 2,000 meters, respectively), and W87 and W88 ground bursts.

		Severe Damage Radius (meters)					Moderate Damage Radius			
Building Type	**VN for Severe Damage**	**300-kt Air Burst**	**300-kt Ground Burst**	**475-kt Air Burst**	**475-kt Ground Burst**	**VN for Moderate Damage**	**300-kt Air Burst**	**300-kt Ground Burst**	**475-kt Air Burst**	**475-kt Ground Burst**
Wood-Framed, Single Story and Multistory	08P0	4,703	3,243	5,438	3,780	06P0	5,866	3,777	6,736	4,405
1-2 Story, Masonry Load-Bearing Walls	10P0	3,849	2,653	4,501	3,092	09P0	4,263	2,930	4,940	3,415
Adobe Walls	11P0	3,376	2,407	4,020	2,805	09P0	4,263	2,930	4,940	3,415
3-5 Story, Masonry Load-Bearing Walls	11P0	3,376	2,407	4,020	2,805	10P0	3,849	2,653	4,501	3,092
Single Story, Very Light Reinforced Concrete Framed	12Q7	3,577	2,686	4,296	3,201	10Q7	4,728	3,361	5,599	4,008
Multistory Monumental (up to 4 stories), Masonry Load-Bearing Walls	12P1	3,022	2,260	3,679	2,643	10P0	3,849	2,653	4,501	3,092
Multistory, Reinforced Concrete Framed (2–10 Stories)	16Q7	1,654	1,762	2,146	2,096	14Q7	2,426	2,051	3,001	2,442
Multistory, Steel Framed (2–10 Stories)	18Q7	923	1,454	1,279	1,727	14Q7	2,560	2,164	3,166	2,576
Multistory, Reinforced Concrete, Earthquake Resistant (2–10 stories)	18Q7	923	1,454	1,279	1,727	16Q7	1,654	1,762	2,146	2,096
Multistory, Steel Framed, Earthquake Resistant	20Q8	521	1,265	786	1,510	17Q8	1,434	1,671	1,924	2,000

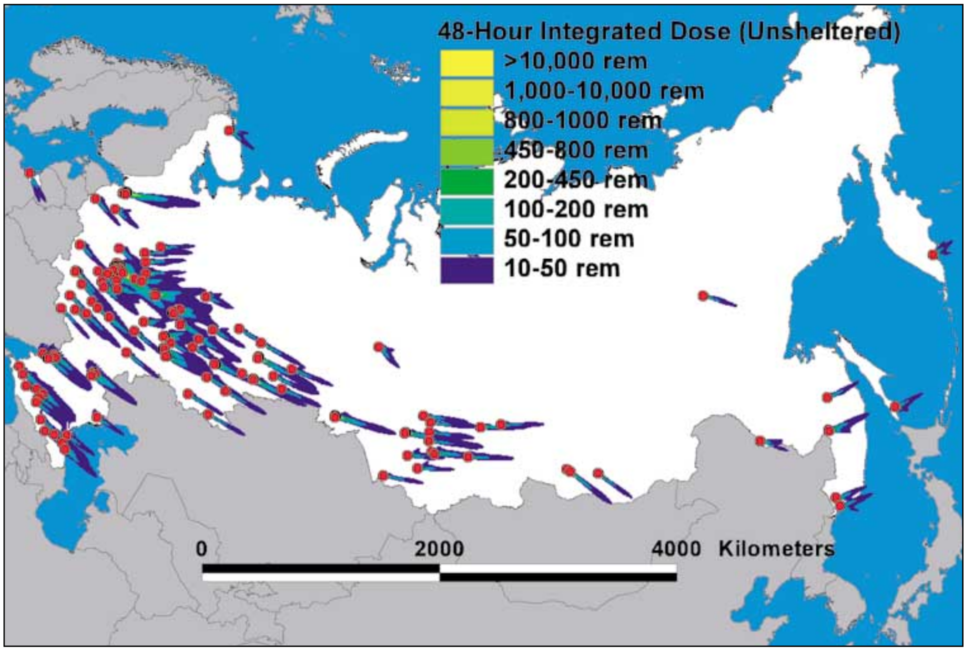


FIGURE 5.7
Fallout Patterns for the Minuteman III Scenario with Ground Bursts

We used the LandScan population distribution to determine the choice of 192 aimpoints for W88 warheads and 150 aimpoints for W87 warheads in order to produce near maximal casualties. We achieved this by summing the population in a four-kilometer-radius neighborhood around each LandScan cell, rank ordering the sums, and selecting as aimpoints cells with the largest summed population but separated by eight kilometers.

Figure 5.2 shows the aimpoints for the Trident submarine calculation and buffered distances illustrative of the Trident on-station patrol areas. Figure 5.3 shows the aimpoints for the Minuteman III scenario. The aimpoints for the Trident scenario

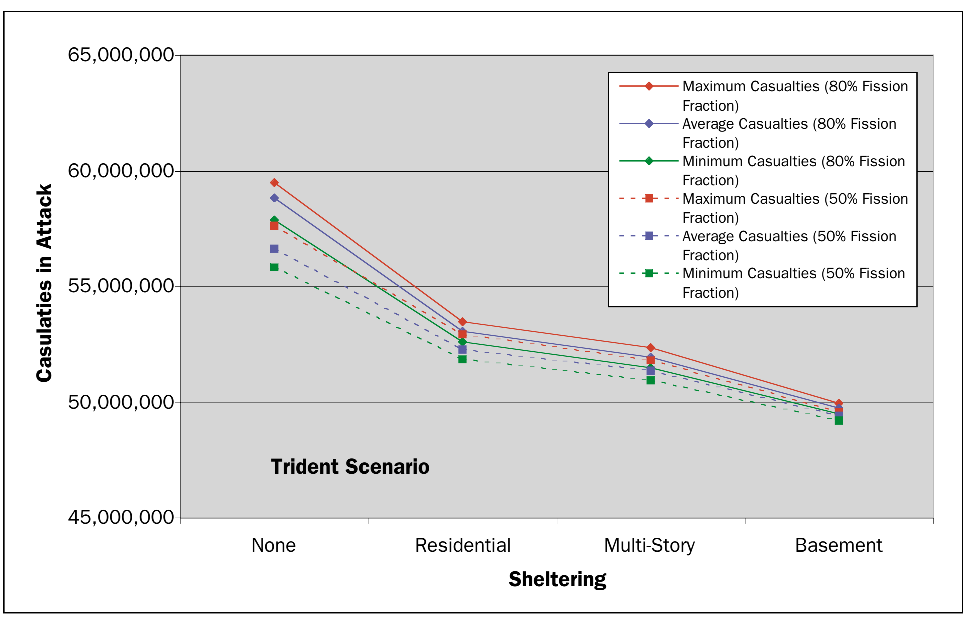


FIGURE 5.8
Casualties as a Function of Sheltering and Warhead Fission Fraction for the Trident Scenario

TABLE 5.5
Estimated Casualty Production in Buildings for Three Degrees of Structural Damage[16]

Building Type	Degree of Structural Damage	Percent of Persons: Killed Outright	Percent of Persons: Seriously Injured (Hospitalization Indicated)	Percent of Persons: Lightly Injured (Hospitalization Not Indicated)
One- and Two-Story Brick Homes (High-Explosive Data from England)	Severe	25	20	10
	Moderate	<5	10	5
	Light	0	<5	<5
Reinforced-concrete Buildings (Nuclear Data from Japan)	Severe	100	0	0
	Moderate	10	15	20
	Light	<5	<5	15

were calculated for European Russia only, assuming an Atlantic Ocean patrol. The aimpoints for the Minuteman scenario were selected throughout all of Russia.

Since the warheads in the Trident scenario are MIRVed, the eight warheads from a single SLBM are constrained to attack targets within an area known as the missile's "footprint." The size and shape of the footprint are determined by several factors, including the amount of fuel in the RV bus used to achieve distinct final trajectories for the MIRVed warheads. We do not know the size and shape of the Trident footprints, but plausibly assume that the Trident scenario aimpoints for warheads from a single missile must not be separated by more than 200 kilometers. The choice of population aimpoints for the Trident scenario is "less optimal" than the Minuteman III scenario due to the constraint posed by the MIRV footprint. A large but geographically isolated city (Kaliningrad or Murmansk, for example) would not be targeted under the Trident scenario because doing so would "inefficiently" allocate all eight warheads to the vicinity of the city.

Damage to Structures

Vulnerability Numbers for various building types are given in Table 5.4, along with the severe and moderate damage radii for W87 and W88 air bursts (at a height of burst of 1,800 meters and 2,000 meters, respectively), and W87 and W88 ground bursts. These calculations show that wood-framed houses can be severely damaged over large areas from a single W87 air burst (69 km^2) or W88 air burst (143 km^2). As would be expected, the severe damage radii for the more sturdy structure types are appreciably smaller.

Table 5.4 lists the building types in order of decreasing vulnerability to nuclear weapons effect. For the first six building types listed in Table 5.4, air bursts will severely damage such structures over about twice the area of ground bursts. But for the last three structure types, lowering the height of burst to ground level actually increases the total area over which such buildings can be severely damaged. Unlike ground bursts, air bursts may produce no local fallout. USSTRATCOM may seek to limit local fallout in the attack for a variety of reasons, including concern over long-term contamination of the environment within or beyond Russia's borders. But if

TABLE 5.6
Casualty and Fatality Results for the Countervalue Attack Scenarios

Scenario	Persons in Reinforced-Concrete Buildings		OTA-Blast Model		Mass Fires Model
	Casualties (thousands)	Fatalities (thousands)	Casualties (thousands)	Fatalities (thousands)	Fatalities (thousands)
Trident, Air Bursts	23,948	17,596	50,671	34,946	54,281
MM III, Air Bursts	14,321	9,373	51,225	31,544	56,247

U.S. intelligence data indicates that Russian cities are comprised predominantly of the more sturdy structure types, ground bursts may be selected in order to maximize the damage and the casualties. For these two scenarios, we compared the results for air bursts and ground bursts.

Casualties

To calculate casualties from these bursts, we used data on the estimated casualty production in buildings for three degrees of structural damage from the World War II bombing of Britain and the nuclear bombing of Japan (see Table 5.5). A highly conservative calculation of the casualties from an attack on Russian cities could assume that the population would reside in reinforced concrete buildings at the time of the attack. Casualties as a function of distance from ground zero would then be computed by combining the damage-distance function derived from the vulnerability number (Table 5.4) with the casualty production estimate (Table 5.5). Figure 5.4 shows casualties as a function of distance from ground zero for a 475-kt W88 air burst (at 2 km height of burst) for: casualties in severely and moderately damaged, reinforced concrete buildings; casualties as would be predicted from the OTA blast model (see Chapter

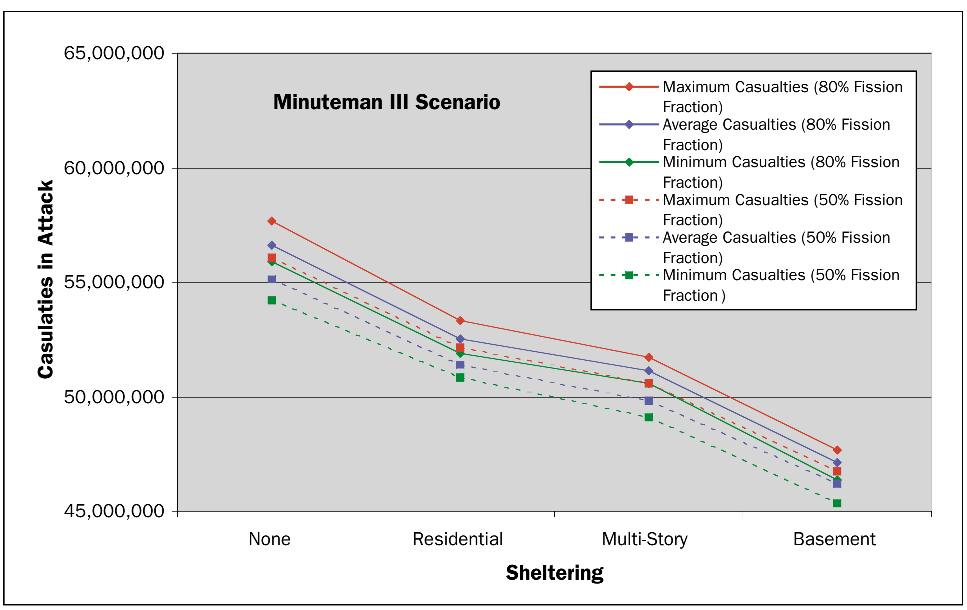


FIGURE 5.9
Casualties as a Function of Sheltering and Warhead Fission Fraction for the Minuteman III Scenario

Three), and casualties as would be predicted from Postol's mass fires model (also see Chapter Three). Figure 5.5 shows the analogous plot for fatalities. For air bursts, casualties and fatalities range from 31 million to 56 million (see Table 5.6). If ground bursts were selected in the attack on Russian cities, the lethality of the extensive fall-out patterns obscures the differences between these models of how casualties occur.

Both the OTA-Blast model and the mass fires model predict that over one-third of all Russians could be killed or severely injured by what is a small fraction of today's arsenal (see Table 5.6 and Figures 5.6 through 5.9). By choosing ground bursts rather than air bursts, casualties would approach 60 million people. This "assured destruction" would occur using only either one Trident submarine (fully-laden with W88 warheads) or one field of 150 Minuteman III warheads.

REVISITING MCNAMARA'S KNEE

The calculations presented above, which utilize Russian population figures for 1999, demonstrate that relatively few Trident-delivered or Minuteman III-delivered nuclear warheads would inflict enormous casualties in what is termed a counter-value attack against Russian cities, probably far more casualties than are usually thought. We now extrapolate the results of this exercise to determine what fraction of the population of the United States, China, Great Britain, or France, for example, can be threatened by such small numbers of high-yield nuclear weapons. If, as McNamara posited, deterrence comes from the threat of destroying 25 percent of an enemy's population, these calculations demonstrate how few weapons are required

TABLE 5.7
NRDC "Assured Destruction" Calculations Using 1999 World Population Data

Country	1999 LandScan Population	25% of the 1999 LandScan Population	Number of 475-kt Weapons Required to Threaten 25% of the Population
United States	258,833,000	64,708,250	124
Canada	28,402,320	7,100,580	11
United Kingdom	56,420,180	14,105,045	19
France	57,757,060	14,439,265	25
Germany	81,436,300	20,359,075	33
Italy	57,908,880	14,477,220	21
Spain	39,267,780	9,816,945	20
All NATO Member Countries[17]	754,933,329	188,730,000	300
Russia	151,827,600	37,956,300	51
China	1,281,008,318	320,252,079	368
North Korea	22,034,990	5,508,747	4
Iran	64,193,450	16,048,363	10
Iraq	20,941,720	5,235,430	4
Syria	14,045,470	3,511,368	2
Libya	5,245,515	1,311,329	2

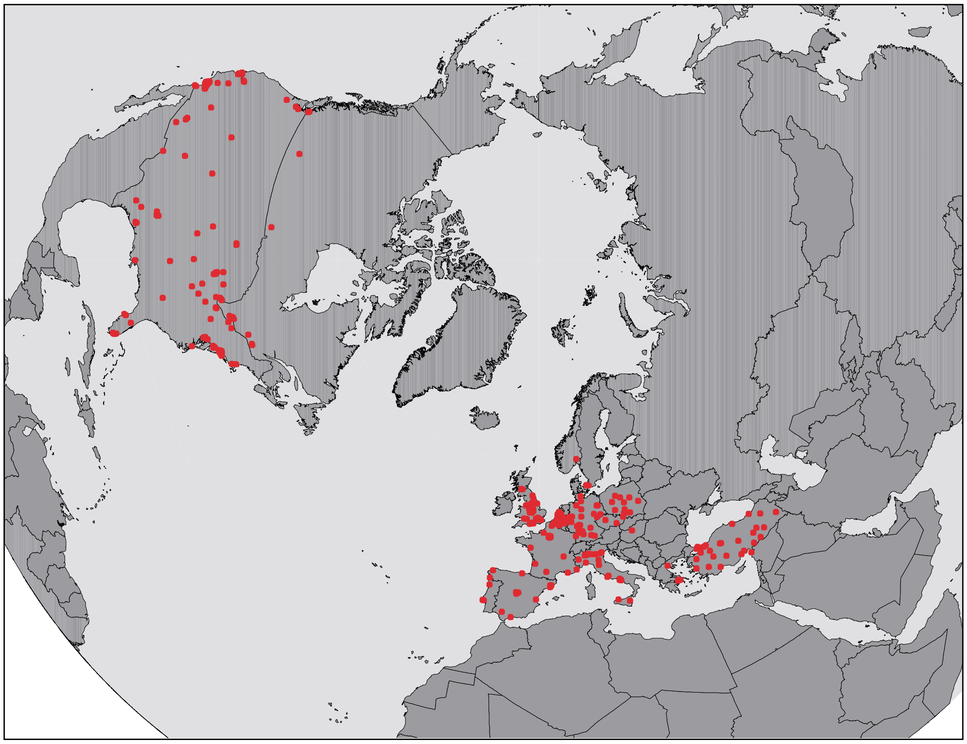
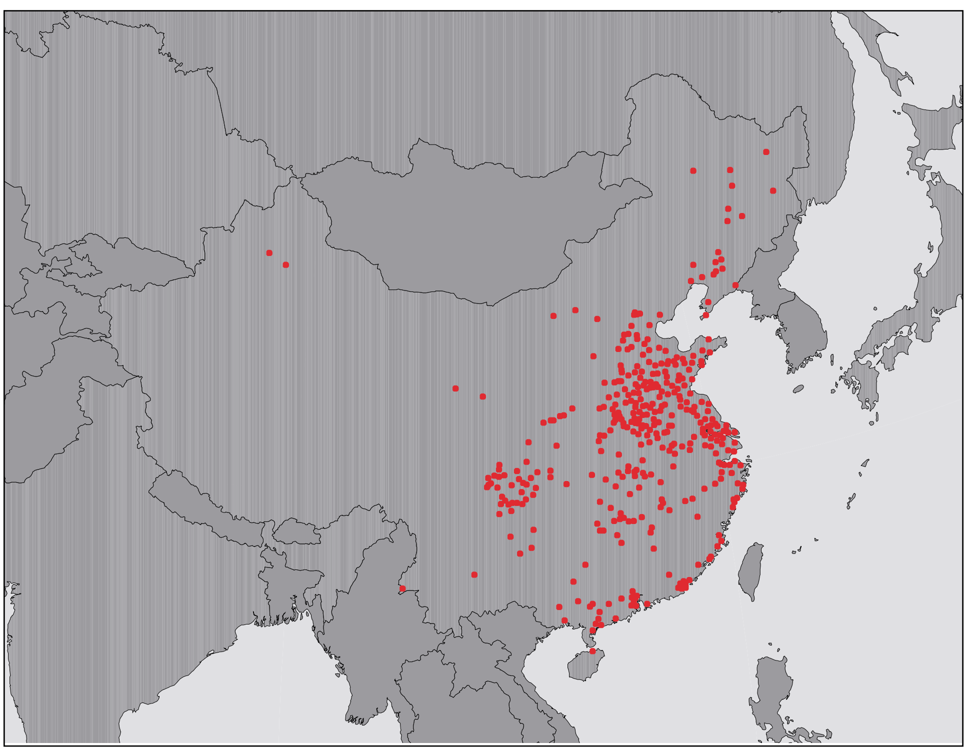


FIGURE 5.10
The 300 Population Targets for All NATO Member Countries and the 368 Population Targets in China
The 300 population targets for all NATO member countries (threatening 189 million persons) shown above, and the 368 population targets in China (threatening 320 million persons) shown below. Today hundreds of high-yield nuclear weapons can threaten hundreds of millions of people in densely-populated urban areas.



If, as McNamara posited, deterrence comes from the threat of destroying 25 percent of an enemy's population, these calculations demonstrate how few weapons are required to deter nations from initiating nuclear attacks.

to deter nations from initiating nuclear attacks. Alternatively, these calculations show the vulnerability of modern societies to thermonuclear arsenals of a size far smaller than those currently deployed by the United States and Russia.

To perform these calculations, population was summed within circles of radius nine kilometers centered on each LandScan population grid cell. For the countries shown in Table 5.7, LandScan cells with the largest nearby population were selected as aimpoints under the constraint that the aimpoints be separated by 18 kilometers (i.e., under the constraint that the nine-kilometer circles are not overlapping). As we have seen in Figures 5.4 and 5.5, nine kilometers is the radius inside which mass fires from 475-kt (W88) air bursts would be anticipated in urban areas using the model of Dr. Postol. Based on our analysis, Table 5.7 shows the numbers of high-yield weapons required to achieve McNamara's "assured destruction" criteria of 25 percent of the population killed. Figure 5.10 contrasts the 300 "assured destruction" aimpoints for all NATO member countries with the 368 such aimpoints in China. What is remarkable about these results is that very few high-yield nuclear weapons can threaten one quarter of the population of the United States, its allies or, under SIOP targeting, its enemies.

CHAPTER SIX

Conclusions and Policy Recommendations

In Chapter Four, we analyzed the consequences of a major counterforce attack on Russia's nuclear forces using approximately 1,300 U.S. nuclear weapons. We concluded that such an attack would result in 11 to 17 million casualties, the majority of which are fatalities, depending upon the time of year. It should be emphasized that 1,300 weapons is well below the START II limit of 3,000 to 3,500, and the proposed START III limit of 2,000 to 2,500 but nevertheless represents a formidable counterforce capability.

Rather than continue with the established pattern of bilateral arms negotiations, the Bush administration has opted to act unilaterally to reduce the number of deployed strategic weapons.[1] Candidate Bush's May 23, 2000 speech on national security issues is the most detailed statement to date and deserves quoting at length.

> *Russia itself is no longer our enemy. The Cold War logic that led to the creation of massive stockpiles on both sides is now outdated. Our mutual security need no longer depend on a nuclear balance of terror.*
>
> *The premises of Cold War nuclear targeting should no longer dictate the size of our arsenal. As president, I will ask the Secretary of Defense to conduct an assessment of our nuclear force posture and determine how best to meet our security needs. While the exact number of weapons can come only from such an assessment, I will pursue the lowest possible number consistent with our national security. It should be possible to reduce the number of American nuclear weapons significantly further than what has already been agreed to under START II, without compromising our security in any way. We should not keep weapons that our military planners do not need. These unneeded weapons are the expensive relics of dead conflicts. And they do nothing to make us more secure.*
>
> *In addition, the United States should remove as many weapons as possible from high-alert, hair-trigger status—another unnecessary vestige of Cold War confrontation. Preparation for quick launch—within minutes after warning of an attack—was the rule during the era of superpower rivalry. But today, for two nations at peace, keeping so many weapons on*

> *high alert may create unacceptable risks of accidental or unauthorized launch. So, as president, I will ask for an assessment of what we can safely do to lower the alert status of our forces. These changes to our forces should not require years and years of detailed arms control negotiations. There is a precedent that proves the power of leadership. In 1991, the United States invited the Soviet Union to join it in removing tactical nuclear weapons from the arsenal. Huge reductions were achieved in a matter of months, making the world much safer, more quickly.*[2]

A year later, President Bush gave a speech at the National Defense University that repeated many of those themes.[3] He spoke of "a vastly different world," in which "today's Russia is not our enemy."

Bush has also made proposals that promise to complicate the quest for deep nuclear arms reductions. These mainly have to do with plans to develop and deploy a National Missile Defense system, which means the inevitable abandonment of the ABM Treaty. We will address these proposals at the end of this chapter, but first let us examine the issue of how far initial unilateral reductions can take us without undue risk to the United States.

The bottom line is that approximately one-third of Russia's citizenry become casualties from an attack with only 150–200 warheads.

If the Bush administration chooses to reduce deployed nuclear forces to about 1,500 warheads there are certain attack options that the U.S. will not be able to carry out. At that level, the U.S. could no longer simultaneously attack Russia's nuclear forces, Russian conventional forces, high-level civilian and military leadership bunkers, and the war support industrial infrastructure. While the U.S. would not have enough warheads to execute these different types of strikes, it could still muster a formidable counterforce capability. While it would be giving up something, it would still keep quite a bit.

Why stop at 1,500 warheads? In Chapter Five we presented two countervalue scenarios. The first used the warheads aboard just a single Trident submarine to attack Russian cities, and this attack resulted in 30 to 45 million casualties. The second scenario used 150 Minuteman III ICBMs in a similar attack on Russian cities with 40 to 60 million casualties. In both instances, the majority of the casualties were fatalities. The Trident attack produced fewer casualties, with more warheads, because the targeting "footprint" is more limited. The bottom line is that approximately one-third of Russia's citizenry become casualties from an attack with only 150–200 warheads. Obviously, through the choice of targets, the United States can hold at risk any number of Russian citizens from zero up to these egregiously high levels with only a few hundred strategic nuclear warheads.

The argument is made in some quarters—including at Strategic Command (STRATCOM)—that directly attacking or holding at risk innocent citizens in urban centers is immoral, while an attack on military forces is less so. As we have shown, because of the indiscriminate nature of the weapons involved, millions of people near military targets will be killed or wounded—what STRATCOM refers to as "collateral damage." This kind of logic leads to the conclusion that China should improve and expand its arsenal from a few hundred warheads to a few thousand so as to capture the high moral ground.

RECOMMENDATIONS

Fortunately there are better options. We recommend the following.

1. Unilaterally reduce U.S. nuclear forces and challenge the Russians to do the same. As a first step, we should unilaterally reduce the U.S. strategic arsenal to a few hundred survivable nuclear warheads, and challenge the Russians to do the same. The United States would still have a more than adequate nuclear deterrent while we waited for Russia to act. Regardless of our actual targeting policy, under their worst-case planning assumptions, our friends in Russia would know that our weapons hold millions of people at risk.

2. Clarify the U.S. relationship with Russia and reconcile declaratory and employment policy. We also recommend a step that derives directly from our findings in this report. We stress the fact that the act of targeting an individual, a group, or a nation defines it as an enemy. It is this first step that we must reverse. We do not target friends or allies—Canada, Britain, Italy, for example—but we do target Russia, China, and several others. The United States still seems to be confused about our relationship to Russia. In his speech at the National Defense University, President Bush said, "Today's Russia is not our enemy." But our actions with regard to nuclear war planning project the exact opposite implication and assumption. If our words and our actions are to correspond, then it is obvious that changes must take place in the way the United States postures its forces and plans for their use. Having a permanent war plan in place that demands widespread target coverage with thousands of weapons on high-alert is a recipe for unceasing arms requirements by the Pentagon and a continuing competition with Russia. It is for this reason that we conclude that the overambitious war plan is the key source of the problem.

3. Abandon much of the secrecy that surrounds the SIOP and reform the process. A corollary problem with the war plan is the high level of secrecy that surrounds it. Because the guidance and the SIOP are so closely guarded, no one can question the assumptions or the logic. The fact that USSTRATCOM has responsibility for drawing up the target list and the plans only contributes to this secrecy. We recommend a change in this procedure. The Omaha nuclear-war-planning function should be brought to Washington and handled by a joint civilian-military staff with Congressional involvement.

4. Abolish the SIOP as it is currently understood and implemented. Having a permanent war plan in place that demands widespread target coverage with thousands of weapons on high alert is a recipe for open-ended arms requirements by the Pentagon and a continuing competition with Russia and others. It is for this reason that we conclude that the over-ambitious war plan is a key obstacle to further deep arms reductions. The current SIOP is an artifact of the Cold War that has held arms reduction efforts hostage. It is time to replace it with something else.

5. Create a contingency war planning capability. We recommend that the war planning functions be handled more like those for conventional forces. The United States should not target any country specifically but create a contingency war planning capability to assemble attack plans in the event of hostilities with another nuclear state. Given the much-reduced set of requirements, the plans should be adequate for any conceivable situation. The new paradigm alleviates the need for large numbers of weapons, and for keeping many of them at high levels of alert. The new approach defuses the implications that go with targeting and would help break the mind-set of the Cold War. We are in agreement with President Bush when he says that we must get beyond the Cold War. We feel though that his approach is not the "clear and clean break with the past" that he hopes for. Instead, by assuming a wider range of uses for nuclear weapons (to counter "new emerging threats"), by making space a theater for military operations, and by considering new or improved warheads for a future arsenal, President Bush is offering more of the same.

It is highly likely that going forward with a missile defense system will have widespread ramifications, including the obvious response of causing certain nations to build more offensive weapons to overwhelm the defense.

6. Reject the integration of national missile defense with offensive nuclear deterrent forces. The Bush administration spokesmen pay little regard to domestic or international criticism of their ideas and policies for ballistic missile defense, and tend to downplay them. In his confirmation hearing, Secretary of Defense Donald Rumsfeld dismissed the ABM Treaty as "ancient history," and a "straightjacket" that limits the choices that America might or must take. If the shoe were on the other foot, it is doubtful that the United States would stand idly by and do nothing if faced with a similar situation. From the Bush perspective, other nations are expected to be calmed by mere pronouncements that we intend no harm, and therefore no one should worry about what we do.

In fact, it is highly likely that going forward with a missile defense system will have widespread ramifications, including the obvious response of causing certain nations to build more offensive weapons to overwhelm the defense. The logic is as old as warfare itself and was the dynamic that the original ABM Treaty was intended to prevent. Prudent military planners, wherever they are, plan on the basis of capabilities rather than intentions, which are much harder to divine. Actions and hardware speak louder than words when militaries view one another. Russian generals and admirals, like our own, build their assumptions on a worst-case analysis. The statement by Admiral Mies could just as easily have been said by his Russian counterpart: "Our force structure needs to be robust, flexible and credible enough to meet the worst threats we can reasonably postulate." From the Russian vantage point, the planners must assume that defense and offense are integrated. The Russians have threatened to renege on several agreements if the United States withdraws from the ABM Treaty, an action not without consequence.[4] For example, the START II Treaty bans MIRVed ICBMs, a positive security advantage for the United States. If the United States proceeds to withdraw from the ABM Treaty, it is likely that Russia would retain its present force of MIRVed ICBMs and possibly even MIRV a single-warhead missile like the SS-27.

A similar situation would confront China, which has long had the ability to put multiple warheads on its ballistic missiles and has chosen not to do so. Currently only a small number, less than two-dozen, Chinese single-warhead missiles can reach the United States. A guaranteed way to increase that number would be for the U.S. to deploy a missile defense system.[5]

Proceeding with national missile defense could create a domino effect. After China reacted to the United States, then India might react to China, and Pakistan might react to India, each building more weapons than they otherwise would. The Bush administration has not addressed how all of this increases U.S. security—even granting the formidable technological hurdles to be overcome to make the system work. The fact of the matter is that pursuit of a defense system is more likely to reduce the security of the United States than enhance it.

It is sometimes made to seem that a shift to defense will supplant deterrence, but this does not seem to be the case according to officials of the new administration. According to remarks made by Secretary Rumsfeld, and reported in *Aviation Week & Space Technology*, his objective is to strengthen the strategic psychology that underlies the ancient precepts of deterrence.[6]

> *By strategic psychology, he [Rumsfeld] means re-fashioning deterrence to preempt war and aggression of all kinds, before the mentalities and conditions that lead to conflict crystallize. Deterrence, by this reasoning, is less a matter a deploying missiles and warheads than understanding an opponent's attitudes, psychology and national character.*

As he told the Senate committee in his confirmation hearing:

> *Credible deterrence no longer can be based solely on the prospect of punishment through massive retaliation. It must be based on a combination of offensive nuclear and non-nuclear defensive capabilities, working together to deny potential adversaries the opportunity and the benefits that come from the threat or the use of weapons of mass destruction (WMD) against our forces [and] our homeland, as well as those of our allies.*

Punishment through massive retaliation of course dates from the Eisenhower administration and has not been our policy for decades, though punishment by selective retaliation has been. Rumsfeld does grant that punishment will remain a component of deterrence. What is different is that it will now be integrated with a defense against missiles. What kind of defense this will be remains an open question, but almost any sort will elicit a response. The technological problems of deploying a workable system are formidable, as other analysts have concluded. Countermeasures are fairly simple to develop and use to overwhelm a defense.[7] More than likely, an attack on the United States using WMD, by terrorist groups or countries other than Russia or China, would probably not be delivered by ballistic missiles, but by cruise missiles or smuggled weapons. In summary, proceeding ahead with a defensive system seems premature until the basic questions of the seriousness and nature of the threat, the cost, the impact on allies and adversaries, and whether the system would work have been answered.

Though packaged as something new, the Bush administration's plans for missile defense are hardly novel and are not the "clear and clean break from the past," to use the President's words. Something more fundamental must occur in order to create real change. As we have seen through our nuclear war simulation model, the place to begin is with an examination of the SIOP war plan and the assumptions upon which it is built.

APPENDIX A
Functional Classification Codes

These codes were developed as part of the U.S. Intelligence Data Handling System (IDHS) for use in the MDIB, NTB, JRADS and other government databases. Source, Reporting Manual for Joint Resources Asessment Database System (JRDS), (Washington, D. C, Joint Chiefs of Staff, March 15, 1999).

Category	***Category Code***
201 00	Atomic energy feed materials
201 10	Uranium metal production
204 00	Moderator materials production
204 10	Heavy water, deuterium oxide
204 20	Synthetic graphite, pile grade
204 30	Beryllium, pile grade
211 00	Petroleum product plants, crude
211 10	Refineries, thermal or catalytic plants
215 00	Pipeline support for petroleum and gaseous fuels, general
215 10	Pipeline support for petroleum and gaseous fuels, pump stations for liquid petroleum
215 20	Pipeline support for petroleum and gaseous fuels, compressor stations for natural gas
218 00	Petroleum product storage
218 10	Civilian/industrial utilization
218 20	Military utilization
218 30	Joint civilian/military utilization
221 00	Light metal and light metal alloys
221 10	Aluminum
232 00	Iron and iron castings
232 10	Iron, pig
233 00	Steel
233 10	Steel production, open hearth furnace shops
233 20	Steel production, basic oxygen furnace (BOF) shops
233 30	Steel production, electric arc furnace shops
234 00	Processed and finished steel products
234 10	Steel processing (roughing) mills
234 20	Basic steel rolling mills
241 00	Aromatic hydrocarbons production, general

Category	Category Code
241 10	Crude or refined benzene production
241 20	Toluene production
243 00	<u>Aromatic hydroxyl production, general</u>
243 10	Phenol production
251 00	<u>Sulfuric acid and metallic sulfates production, general</u>
251 10	Sulfuric acid production
251 20	Metallic sulfates
252 00	<u>Ammonia, nitric acid, and nitrates</u>
252 10	Ammonia
252 20	Nitric acid
252 30	Nitrates
253 00	<u>Hydrochloric acid and chlorides production, general</u>
253 10	Hydrochloric acid production
253 20	Chlorine dioxide, chloride, chlorate, chlorite, perchlorate, chloric, hypochlorite, hypochlorous, chlorous compound production, general
254 00	<u>Gaseous chemical products production, general</u>
254 12	Argon liquid state
254 20	Chlorine production
254 30	Helium, specific state unknown
254 40	Hydrogen, specific state unknown
260 00	<u>Monomers, manmade fibers, filaments, polymers, resins, and pesticides, general</u>
261 00	Monomers Production
262 00	<u>Manmade fibers (filaments) production</u>
263 00	<u>Thermoplastic polymers and resins production</u>
264 00	<u>Thermosetting polymers (resins)</u>
264 10	Synthetic rubbers (elastomers) production
265 00	<u>Composite plastics, general</u>
401 00	<u>Basic and applied nuclear research and development</u>
401 10	Basic nuclear research laboratories
402 00	<u>Aircraft research</u>
402 10	Aircraft research, airframe

Category	Category Code
402 20	Aircraft research, aircraft engine
402 30	Airframe component research
402 40	Aircraft engine component research
403 00	<u>Electronic and communication research, general</u>
403 40	Radar equipment, all types
403 60	Computers
403 70	Electronic countermeasures
403 80	Electro-optical, including lasers and infrared devices
403 90	Miscellaneous Electronics
404 00	<u>Ordnance research and development</u>
404 10	Armored vehicle research, development, and/or testing
404 20	Artillery research, development, and/or testing
404 40	Munitions research, except underwater
404 50	Aerial bomb research
404 60	Explosives research, development, and/or testing
404 70	Underwater ammunition, research
405 00	<u>Chemical warfare and biological defense research</u>
405 10	Chemical warfare research
405 20	Biological defense research
406 00	<u>Shipbuilding research and development, general</u>
406 50	Shipbuilding equipment, ship repair yard equipment, and shipbuilding materials research and development
408 00	<u>Guided missile and space system research, development, and testing</u>
408 10	Guided missile and space system, airframe development and testing
408 20	Guided missile and space system, propulsion equipment development
408 30	Guided missile and space system, guidance and control equipment development
408 50	Guided missile and space system, propulsion-testing facilities (hot firing stands)
408 70	Guided missile and space system, propellant research
409 00	<u>General research institutes</u>
409 30	General research institutes supporting military associated research and development
41x xx	<u>Communications facilities, transmission, and reception</u>
411 21	Radio relay terminal
411 4x	Satellite ground station

Category	*Category Code*
414 30	Multipurpose switching center
419 00	Special purpose, communications-electronics facilities, general
419 10	Special purpose, strategic connectivity locations
419 20	Special purpose, national government control locations
42x xx	Electric power plants and distribution facilities
420 00	Electric power plants, general
421 00	Thermal electric power plants, non-nuclear
421 10	Thermal electric power plants, steam turbine
421 40	Thermal electric power plants, nuclear
421 90	Thermal power plants, combination
422 00	Hydroelectric power plants
431 10	Desalination facilities
439 00	Dams
44x xx	Road and water transportation
441 00	Bridges, highway (including viaducts, trestles, and grade separations)
441 20	Bridges, highway
442 00	Tunnels, highway
444 00	Piers and Docks
445 30	Highway crossing a dam
447 00	Lines of communication, highway
45x xx	Railroad tracks and yards
451 00	Bridges, railroad (including viaducts, trestles, and grade separations)
451 10	Bridges, railroad
452 00	Tunnels, railroad
452 10	Tunnels (except underwater)
452 20	Tunnels (underwater)
453 00	Railroad yards

Category	Category Code
453 10	Classification yards
453 20	Freight terminals
455 00	Railroad crossing a dam
456 00	Facilities for repair of railroad equipment
457 00	Lines of communication, railroad
459 00	Rail transport facilities
459 20	Freight terminals (interface)
459 70	Traffic control and communications facilities
459 71	Centralized train control
459 72	Computer
459 80	Interlocking
461 20	Inland locks and canals
471 00	Channel overpasses, locks, overhead canals, and aqueducts
474 00	Port facilities
5xx xx	Industrial/economic
520 00	Communication and electronic equipment
521 40	Radar production, all types
522 00	Electronic components production
522 30	Microelectronics components/semiconductor production
523 00	Computer equipment production
524 00	Electronic countermeasures, (ESM), counter-countermeasures, (ECCM), and electronic support measures, (ESM) equipment production
525 00	Electro-optical equipment production [excludes television]
525 10	Laser weapons production
525 20	Nonweapon lasers production [includes rangefinders, target designators, and industrial lasers]
525 30	Infrared devices production [includes night vision and heat seekers]
526 00	Miscellaneous electronics equipment production

Category	*Category Code*
526 10	Navigation equipment production
526 20	Hydroacoustic equipment production
60x xx	<u>Nuclear industry</u>
601 00	<u>Production reactors</u>
601 10	Nuclear materials production reactors
601 40	Nuclear fuel processing facilities
601 41	Nuclear fuel processing facilities, weapons use
601 42	Nuclear fuel processing facilities, non-weapons use
602 00	<u>Isotope separation and production facilities</u>
602 10	U-235 isotope separation, gaseous diffusion
602 50	Lithium-isotope separation
603 00	<u>Nuclear weapon fabrication</u>
604 00	<u>Nuclear weapons storage</u>
604 20	Nuclear weapons storage site, operational
611 00	<u>Airframe production and final assembly of finished aircraft</u>
611 10	Fighters
611 20	Reconnaissance aircraft production and assembly
611 30	Bombers production and assembly
611 40	Helicopters
611 50	Transport aircraft production and assembly
611 70	Communications/utility aircraft production and assembly [includes liaison, observation, light civilian aircraft and gliders.]
611 80	Trainer aircraft production and assembly
612 00	<u>Aircraft engine production and assembly, general</u>
612 40	Gas turbine aircraft engines production and assembly
621 00	<u>Small arms and automatic weapons through 19MM</u>
622 00	<u>Artillery and naval ammunition, 20mm and larger</u>
623 00	<u>Mortar ammunition</u>
624 00	<u>Free (unguided) rockets</u>
625 00	<u>Aerial bombs, except depth charges</u>
626 00	<u>Underwater ammunition production</u>

Category	***Category Code***
626 10	Depth charges
626 20	Special antisubmarine ammunition
626 40	Sea mines
626 50	Torpedoes
627 00	Missile warheads production
632 00	Weapons production, 20mm and larger, general
633 00	Mortars
634 00	Artillery, over 70mm
635 00	Rocket and grenade launchers
641 00	Motor vehicle production, general [excludes motorcycles]
641 11	Truck production (up to 7 metric tons)
641 12	Truck production (7.1 to 24.99 metric tons)
641 13	Truck production (over 25 Metric Tons)
644 00	Combat motor vehicle production, general
644 10	Tank and assault gun production
644 30	Armored infantry combat vehicle production
644 40	Armored personnel carriers production
646 00	Combat vehicle repair (major overhaul and rebuild)
647 00	Automotive engine production, general
647 10	Truck engine production
647 50	Combat vehicle engine production
661 00	Chemical warfare production, general
661 10	Chemical warfare, agents production
661 20	Chemical warfare, munitions production, general
661 21	Chemical warfare production, munitions, aerial
661 22	Chemical warfare production, munitions, ground
661 30	Chemical warfare production, protective equipment, general
661 31	Chemical warfare production, protective equipment, gas masks
661 32	Chemical warfare production, protective equipment, clothing
661 33	Chemical warfare production, protective equipment, detection equipment
661 34	Chemical warfare production, protective equipment, decontamination equipment
661 35	Chemical warfare production, protective equipment, agent antidotes

Category	*Category Code*
661 40	Chemical warfare production, weapons, general
662 00	Chemical warfare storage, general
662 10	Chemical warfare storage, bulk agents
662 20	Chemical warfare storage, munitions
662 30	Chemical warfare storage, bulk agents and munitions
662 40	Chemical warfare storage, related equipment only
671 00	Shipyards, basic construction
671 10	Naval vessels
671 20	Submarine construction and fitting out
671 30	Commercial vessels
672 00	Shipyards, fitting out, repairing, converting, or modifying
672 10	Naval vessels
672 20	Submarine repair, conversion, or modification
672 30	Ship repair, commercial vessels
680 00	Guided missile and space system production and assembly, general
681 00	Strategic land-based missile production, general
681 10	Intercontinental ballistic missiles
681 20	Intermediate-range ballistic missile
681 30	Medium-range ballistic missile production
681 40	Ground-launched surface-to-surface cruise missiles
682 00	Tactical land-based missile production, general
682 10	Short-range ballistic missiles
682 20	Antitank missiles
682 30	Surface-to-surface cruise missiles
683 00	Naval missile production, general
683 10	Strategic ballistic missiles
683 20	Tactical ballistic missiles
683 30	Aerodynamic cruise missiles
683 40	Antisubmarine warfare missiles
683 50	Naval surface-to-air missiles
684 00	Surface-to-air antiballistic missile production, general
684 10	Strategic surface-to-air missiles
684 20	Tactical surface-to-air missiles
684 30	Endo-atmospheric antiballistic missiles
684 40	Exo-atmospheric antiballistic missiles

Category	Category Code
685 00	Air-to-surface missile production
685 10	Strategic air-to-surface missiles
685 20	Tactical surface-to-air missiles
686 00	Air-to-air missile production, general
687 00	Space systems production
687 10	Space launch vehicles (0.1-1.9 meters in diameter)
687 20	Space launch vehicles (greater than 2.0 meters in diameter)
687 30	Satellites/scientific capsules/manned vehicles
687 40	Research and meteorological rockets
687 50	Other research rockets
688 00	Drone and remotely piloted vehicle production
690 00	Explosive, production, and storage
691 00	Industrial explosive production
691 10	Dynamite production
691 20	Black powder production
691 30	Ammonium nitrate production
692 00	Propellant for conventional weapon systems production, general
693 00	High explosives production, general
693 50	Explosive mixture production
7xx xx	Urban features and population
701 00	Urban area
702 xx	Cities/towns
702 yy	Population concentration
730 00	Military industrial areas
741 00	Government control centers, national level
741 10	Government control centers, urban administrative
741 30	Government control centers, command posts
742 00	Government control centers, state level, general (second level)
742 10	FEMA headquarters and regional centers

Category	Category Code
743 00	Municipal government control centers (city halls)
752 00	Military bases
772 00	Financial institutions
772 10	Federal reserve banks
772 11	Federal reserve, bank branches
772 12	Federal reserve, bank regional offices
772 20	Federal reserve, communications and records center
800 00	Airfields
800 30	Arctic staging base
801 50	Heliport
811 00	National aviation headquarters
814 00	Naval aviation headquarters
814 10	First echelon
814 20	Second echelon
815 00	Aviation headquarters and schools
815 10	Air transport headquarters
82x xx	Air defense command and control installations
820 00	Air defense headquarters and control center
820 20	Second echelon
820 60	Sub-region air defense control facilities
821 10	Air defense command facilities, first echelon
821 30	Air defense command facilities, third echelon
822 4x	Air defense command, command post bunker
823 20	Air defense administrative headquarters, second echelon
823 30	Air defense administrative headquarters, third echelon
841 00	Space system operational facilities, general
841 10	Space launching facilities
841 20	Space tracking, transmitting and readout stations, general
841 21	Space tracking radars
841 22	Radio telescopes
841 23	Optical tracking systems

Category	***Category Code***
841 24	DSP-related ground stations
841 30	Space coordinating and computer centers
845 00	Military space systems
845 52	Space detecting and tracking system (SPADATS)
845 53	SPADATS alternate control centers
845 56	Radar system
845 57	Optical tracking system
845 61	Space surveillance system (NAVSPASUR) control centers
845 63	Radio transmitters
845 64	Radio receivers
851 00	Radar installations, early warning, surveillance, detection, tracking, and acquisition
851 10	Radar installations, early warning/acquisition, aerodynamic
851 11	Radar facilities, early warning, aerodynamic
851 13	Radar facilities, acquisition, aerodynamic
851 20	Radar installations, ballistic missile early warning/satellite detection and tracking
851 30	Radar installations, ballistic missile early target tracking and acquisition
851 40	Radar installations, over-the-horizon detection
851 52	Radar facilities, coastal surveillance/early warning
852 00	Radar installations, ground control intercept
852 10	Fixed-radar installations
853 00	Radar installations, missile control
853 25	Radar facilities, missile control, SAM, SA-5
856 00	Air traffic control and landing aids
861 00	Air depots, general
861 10	Air depots
862 00	Air conventional ammunition depots
863 00	Aircraft maintenance and repair bases, general
863 10	Supporting military aircraft
863 20	Supporting civilian aircraft
864 xx	Airfield underground/cave support facilities
865 00	Air logistics headquarters, general
865 20	Air logistics headquarters, area

Category	***Category Code***
87x xx	<u>Surface-to-surface and surface-to-air missile installations</u>
871 00	<u>Surface-to-surface missile sites, fixed, general</u>
871 10	Intercontinental ballistic missile sites
871 20	Intermediate-range ballistic missile sites
871 30	Medium-range ballistic missile sites
871 40	Surface-to-surface missile sites, various
871 50	Surface-to-surface missile sites, cruise
871 60	Short-range ballistic missile sites
872 00	<u>Surface-to-surface and surface-to-air missile sites/complexes</u>
873 xx	<u>Missile sites/complexes, defensive</u>
874 00	<u>Missile headquarters, surface-to-surface</u>
874 10	Missile headquarters, national level
874 20	Missile headquarters, army or corps level
874 30	Missile headquarters, division level
874 40	Missile headquarters, regimental level
874 50	Missile headquarters, battalion level
874 60	Missile headquarters, brigade level
875 xx	<u>Missile sites/complexes, surface-to-air, defensive</u>
875 x1	Missile site, ABM
876 00	<u>Missile support facilities, offensive</u>
876 10	Missile support facilities, ICBM
876 30	Missile support facilities, MRBM
876 40	Missile support facilities, ground tactical
876 50	Missile support facilities, cruise offensive
876 60	Missile support facilities, (various)
878 00	<u>Surface-to-surface missile launch control facilities</u>
878 10	Intercontinental missile launch control facilities
878 20	Intermediate-range missile control sites
878 30	Medium-range missile control sites
878 40	Cruise missile control sites
879 00	<u>Missile support facilities for ship-borne missiles or coastal defense missiles (bunkers)</u>
879 10	Support facilities for surface ship-borne missiles
879 20	Support facilities for submarine-borne missiles
88x xx	<u>Surface-to-surface missile sites, offensive</u>

Category	***Category Code***
881 xx	Surface-to-surface missile systems
881 17	SS-24 Rail Deployment Site
89x xx	National combined, and joint command
891 00	National command authorities, facilities
895 10	Joint command post facilities
900 00	Ground force installations
900 10	Ground force Reserve Components' installations
901 00	Troop installations, fixed
901 10	Barrack areas, posts, and stations
901 20	Training centers/maneuver areas
902 00	Troops in the field (assembly and staging areas)
902 10	Concentrations of tactical troops
902 20	Assembly and staging areas
910 00	Ground force headquarters
910 10	National headquarters
910 20	Group headquarters
910 30	Ground-force headquarters, military district/regional headquarters
911 00	Ground forces materiel support headquarters/echelons
911 10	Commodity commands and echelons
911 20	Logistics management and control echelons
912 00	Military transportation headquarters/echelons
912 40	Tenant facilities
913 00	Ground forces service support headquarters/echelons
914 00	State area command headquarters
920 00	Ground force materiel storage and depot maintenance facilities
920 10	Ammunition storage and depot maintenance facilities
920 70	Pre-positioned combat equipment afloat
931 00	Automatic data processing installations
941 30	Defense logistics depots

Category	***Category Code***
95x xx	Naval
951 00	Surface ship bases
951 10	Cruiser and/or destroyer force bases
951 20	Navy primary defense force bases
952 00	Submarine bases
952 10	Supporting, missile-armed submarines
952 30	Operational submarine bases supporting non-missile-armed submarines
952 50	Submarine bases for maintenance and repair of submarines
955 00	Specialized naval activities
955 30	Photographic laboratories
955 52	Ship-borne search and rescue
956 00	Naval and maritime moorings
956 10	Naval fleet reserve
960 00	Naval headquarters
961 00	National naval headquarters
962 00	Naval headquarters (fleet and force)
962 10	Submarine force headquarters
962 20	Cruiser-destroyer force headquarters
962 30	Naval-base defense-force headquarters
962 40	Fleet rear service auxiliary force headquarters
962 50	Headquarters, force level, unspecified
971 00	Naval general materiel storage
971 10	Naval and materiel storage, located on a naval or coast guard base
971 20	Naval general materiel storage, located off base
972 00	Naval conventional ammunition and/or ordnance storage
972 10	Naval conventional ordnance storage located on a Naval base
972 20	Naval conventional ordnance storage, located off base

APPENDIX B
Data Fields in the NRDC Russian Target Database

Target ID
Category Code (5 digit code used by the U.S. government)
Target Name
Target Class (NF, OMT, L-C3, or WSI)
Target Category
Target Type
Organization
Unit Abbreviation (Used in 1997 CFE Data Declaration)
Degrees North (Latitude)
Minutes North (Latitude)
Seconds North (Latitude)
Degrees East (Longitude)
Minutes East (Longitude)
Seconds East (Longitude)
Elevation (meters)
Address, street name and number
Location (nearby town)
Administrative Region (Oblast, Kray, Autonomous Republic, Autonomous Oblast, Autonomous Okrug)
Military District (Northern, Moscow, North Caucasus, Urals, Volga, Siberian, Transbaikal, Far East)
Postal Zip Code
Country
Description/Function
Deployed ICBM Launchers (Number)
Deployed ICBMs (Number)
Deployed SLBMs (for naval bases only) (Number)
Deployed Warheads (Number)
Non-Deployed ICBM Launchers (Number)
Non-Deployed ICBMs (Number)
Training ICBM Models (Number)
ICBM Emplacement Equipment (Number)
ICBM Training Launchers (Number)
Non-Deployed SLBMs (Number)
Area (sq km) (for Road-Mobile ICBMs)
Trains/Vehicles (Road-Mobile and Rail-Mobile ICBMs) (Number)
Airfield (enter “AF” if target is an Airfield)
Runway Length (meters)
Airfield Suitability
Unit Types
1st Higher Echelon
2nd Higher Echelon
Personnel (Number)
Combat Aircraft (Number)

CCT Aircraft (Number)
Training Aircraft (Number)
Tu-22 Blinder (Number)
Tu-22M Backfire (Number)
Tu-160 Blackjack (Number)
Tu-95M Bear (Number)
Tu-16 Badger (Number)
Su-17 Fitter (Number) (Fighter)
Su-22 Fitter (Number) (Fighter)
Su-24 Fencer (Number)
Su-25 Frogfoot (Number) (Fighter)
Su-27 Flanker (Number)
MiG-21 Fishbed (Number) (Fighter)
MiG-23 Flogger (Number)
MiG-25 Foxbat (Number) (Fighter)
MiG-27 Flogger (Number)
MiG-29 Fulcrum (Number) (Fighter)
MiG-31 Foxhound (Number) (Fighter)
L-29,-39 Training Planes (Number)
Attack Helicopters (Number)
Combat Support Helicopters (Number)
Unarmed Helicopters (Number)
Other (Number)
Tanks (Number)
Armored Combat Vehicles (ACV) (Number)
Armored Personal Carriers (APC) and Armored Infantry Fighting Vehicle (AIFV) (Number)
AVLB (Number)
Artillery (Number)
Primary Fuel (used in power plants)
Capacity
Unit of Measure (e.g., MWe for power plants, bbl/d for oil refineries)
River (for hydroelectric power plants only)
Pipelines from pipeline node
VLF Transmitter Site
LF Transmitter Site
MF Transmitter Site
HF Transmitter Site
UHF Transmitter Site
SHF Transmitter site
EHF Transmitter Site
Priority (identifies potential targeting scenarios)
VT: Physical Vulnerability Type (P = Point; E = Equal Target Area)
VN1: Physical Vulnerability Number for Point Type Targets

VN2: Physical Vulnerability Number for Equal Target Area Type Targets
ONC (the Operational Navigational Chart where the target is located)
JOG (the Joint Operations Graphic where the target is located)
CFE (whether the target is listed in the 1997 CFE data declaration)
References (the sources of the data for the target description/function)
Date when the target information was last modified
Last Modified by (initials of the person that last modified the data fields for this target)
Coordinate Reference (the reference for the target coordinates)
Additional Comments

APPENDIX C
NRDC Russian Target Database Target Classes, Categories, and Types

(Abbreviations or acronyms in bold.)

Nuclear Forces (**NF**)
- ICBM (Fixed) (**ICBM-F**)
  - ICBM-Fixed Silo (**S**)
  - Launch Control Center for Silo-Based ICBM (**LCC**)
  - Strategic Missile-Main Operating Base (**SM-MOB**)
  - Strategic Missile Base (Troops) (**SMB-T**)
- ICBM (Mobile) (**ICBM-M**)
  - Road Area (road-mobile ICBMs) (**RDA**)
  - Railroad Parking Site (rail-mobile ICBM) (**RRPS**)
  - Railroad Entrance/Exit (**RRE/E**)
  - Strategic Missile (Mobile) Dispersal Base (Hardened) (**SMMDB-H**)
  - Strategic Missile (Mobile) Dispersal Base (Unhardened) (**SMMDB-U**)
  - Strategic Missile-Main Operating Base (**SM-MOB**)
  - Strategic Missile Base (Troops) (**SMB-T**)
  - ICBM Road-Mobile Boundary Coordinates (**RDM-B**) [not targets]
- SLBM Bases and Forces (**SLBM)**
  - SSBN Main Operating Base (**SSBN-MOB)**
  - Naval Base Frequented by SSBNs (dispersal area) (**NB**)
  - Shipyard Used to Repair/Overhaul SSBNs (dispersal area) (**NY**)
  - SLBM-Loading Facility (**SLBM-LF**)
  - SSBN Dispersal Areas (Unhardened) (**SSBN-DA-U**)
  - SSBN Dispersal Areas (Hardened) (**SSBN-DA-H**)
  - SSBN At-Sea Dispersal Areas (**SSBN-ASDA**)
- Strategic Air Forces (**SAF**)
  - Strategic Bomber Main Operating Base/Airfield (**SBB**)
  - Aerial Refueling Main Operating Base (**AR-MOB**)
  - Former Strategic Bomber Main Operating Base/Airfield (**FSBB**)
  - Strategic Bomber Dispersal Base (**SBDB**)
  - Strategic Bombers Arctic Staging Base (**AS**)
  - Strategic Bomber Units (**SBU**)
  - Heavy Bomber Flight Test Center (**HBFTC**)
  - Heavy Bomber Training Unit (**HBTU**)
- Non-Strategic Nuclear Navy (**NSNN**)
  - Non-Strategic Nuclear Navy-Main Operating Base (**NSNN-MOB)**
  - Navy Base Frequented by SSGNs and Nuclear-Capable Surface Ships (dispersal area) (**NB**)
  - Shipyard Used to Overhaul SSGNs and Nuclear-Capable Surface Ships (dispersal area) (**NY**)
  - Cruise Missile-Loading Facility (**CM-LF**)
- Non-Strategic Nuclear Air Forces (**NSNAF**)
  - Medium Range Bomber Main Operating Base (**MRBB**)
  - Tactical Air Forces/Frontal Aviation Base (**FAB**)

Air Force Bombers Units **(AFBU)**
Non-Strategic Nuclear Naval Aviation (**NSNNA**)
Naval Aviation Main Operating Base (**NA**)
Naval Aviation Unit **(AAU)**
Non-Strategic Nuclear Army (**NSNA**)
Non-Strategic Nuclear Army-Main Operating Base (**NSNA-MOB)**
Nuclear Warhead Storage (**NWHS**)
Nuclear Warhead Storage and Maintenance Facility, General/Possible/Unknown Use (**NWHSF**)
Nuclear Warhead Storage and Maintenance Facility (SRF) (**NWHSF-SRF**)
Nuclear Warhead Storage and Maintenance Facility (National Level) (**NWHSF-NL**)
Nuclear Warhead Storage-Main Operating Base (**NWHS-MOB**)
Nuclear Weapons Storage Facilities (At Airfields During Alert) (**NWHSF-A**)
Nuclear Weapons Storage Facilities (Primarily Naval) **(NWHSF-N)**
Nuclear Weapons Storage Facilities (At Production Sites) **(NWHSF-P)**
Warhead Storage Site Boundary Coordinates (**WHS-B**) [not targets]
Ground Forces Nuclear-Capable Units (**GFNU**)
Nuclear-Capable Missile Brigade Site (**NMBS)**
Nuclear-Capable Artillery Division Site (**NADS**)
ABM Forces (**ABM**)
Anti-Ballistic Missile Silo (**ABM-S**)
Anti-Ballistic Missile Tracking Radar (**ABM-TR**)
Anti-Ballistic Missile-Main Operating Base (**ABM-MOB**)
Anti-Ballistic Missile Launcher (Dismantled) (**ABM-L-C**)
Strategic Missile Test Launch Facilities (**SMTLF**)
Missile (ICBM) Test Silo (**MTS**)
Missile Soft Site Launcher (**MSSL**)
Missile Test Site Base (**MTSB)**
Missile Test Site (Troops) (**MTS-T)**
Strategic Forces Storage Facilities (**SFSF**)
ICBM Storage Facility (**ICBM-SF)**
SLBM Storage Facility (**SLBM-SF**)
Strategic Bomber Storage Facility (**SB-SF**)
Strategic Forces Maintenance Facilities (**SFMF**)
ICBM Maintenance Facility (**ICBM-MF**)
ICBM Mobile Launcher Repair Facility (**ICBM-MLRF**)
SLBM Maintenance Facility (**SLBM-MF**)
Strategic Bomber Maintenance Facility (**SB-MF**)
Strategic Forces Conversion/Elimination Facilities (**SFEF**)
ICBM Conversion/Elimination Facility (**ICBM-EF**)
SLBM Conversion/Elimination Facility (**SLBM-EF**)
Strategic Bomber Conversion/Elimination Facility (**SB-EF**)
Nuclear Forces Transportation Unit Locations (**NFTU**)

- Strategic Missile Transport Troops (**SMTT**)
- Air Forces Nuclear Transport Unit (**AFNT**)

Nuclear Forces Training Facilities (**NFTF**)
- ICBM Silo Training Launcher (**ICBM-STL**)
- Missile Training Facility (**MTF**)
- Missile Static Display (**MSD**)
- 12th Main Directorate (12th GUMO) Training Center (**GTC**)
- Air Forces Nuclear Training Centers (weapon delivery) (**AFNTC**)

Other Military Targets-Conventional Military Forces (**OMT)**

Airfields (**AF**)
- Air Defense Base (**ADB**)
- Air Force Base (**AFB**)
- Aviation Sports Club [Aviation Training Base] (**ASC**)
- Civilian Airport (**CIV**)
- Frontal Aviation Base (**FAB**)
- Heliport (**HELO**)
- International Airport (**IAP**)
- Medium Range Bomber Main Operating Base (**MRBB**)
- Military Airfield (**MIL**)
- National Civil Leadership (**NCL**)
- National Military Leadership (**NML**)
- Naval Aviation (**NA**)
- Unknown Type (**UNKN**)

Air Force Units, Non-Nuclear **(AFUC)**
- Air Forces Air Defense Units (**AFAD**)
- Air Forces Base (**AFB**)
- Air Forces Bomber Unit (**AFBU**)
- Air Forces Composite Unit (**AFCU**)
- Air Forces Fighter Unit (**AFFU**)
- Air Forces Ground Attack Units (**AFGA**)
- Air Forces Reconnaissance Unit (**RCON**)
- Air Forces Transportation Unit (**AFTU**)
- Air Forces Special Purpose Unit (**AFSPU**)
- Aviation Maintenance Facility (**AMF**)
- Flight Training Facilities **(FTF**)

Naval Aviation Units, Non-Nuclear (**NAUC**)
- Naval Aviation Base (**NAB**)
- Naval Aviation Unit (**NAU**)

Helicopter Units (**HU**)
- Combat Helicopter Unit (**CHU**)
- Helicopter Training Unit (**HTU**)

Space Related Facilities (**SPACE**)
- Space Launch Facilities (**SLF**)

- Anti-Satellite Systems (**ASS**)
- Air Defense Missiles (**ADM**)
  - Air Defense Missile Base (**ADMB**)
  - Surface-to-Air Missile Site (**SAM-S**)
  - Surface-to-Air Missile-Radar (**SAM-R**)
  - Tactical Surface-to-Surface Missiles (**TSM**)
  - Missile Brigade Site (**MBS)**
- Naval Ship Facilities (**NSF**)
  - Navy Base (**NB**)
  - Navy Shipyard (**NY**)
  - Shipping Dock/Pier (**SD**)
  - Ship Anchorage (**SA**)
- Ground Forces Sites (**GFS**)
  - Artillery Unit (**ARTY**)
  - Airborne Unit (**ABRN**)
  - Battle Tank Unit (**BTU**)
  - Armored Vehicle Unit (**TAAS**)
  - Communication/Signal Unit (**COM**)
  - Electronics/Intl/Countermeasures Unit (**ELEC**)
  - Federal Border Service Troop Site (**FBST**)
  - Material Support Unit (**MAT**)
  - Motorized Rifle Unit (**MRU**)
  - Motorized Transport Unit (**MTU**)
  - MVD Internal Troop Site (**MVDS**)
  - Nuclear, Biological and Chemical Unit (**NBC**)
  - Reconnaissance Unit (**RCON**)
  - Rocket Launcher Unit (**RLU**)
  - Security Units (**SCTY**)
  - Spetnaz Unit (**SPTZ**)
  - Weapon Arsenals (Conventional Weapons/Munitions Storage) (**WAS**)
  - Medical Unit (**MED**)
- Naval Shorebased Troops (**NSTS**)
  - Naval Infantry Unit (**NIU**)
- Chemical Weapons (**CW**)
  - Chemical Weapon Storage Site (**CWSS**)
- Conventional Forces Training (**CFT**)
  - Ministry of Defense Academy (**MOD-A**)
  - Ground Forces Training Site (**GFTS**)
  - Chemical Weapons Training Facility (**CWTF**)
  - Chemical Weapons Defense Academy (**CWDA**)

Leadership-Command, Control, and Communications (**L-C3**)

- National Government Leadership/Support (**NGL**)
  - Executive Leadership Facility (**ELF**)

- Executive Leadership Facility Underground (**ELF-UG**)
- Legislative Leadership Facility (**LLF**)
- Legislative Leadership Facility Underground (**LLF-UG**)

National-Level Military Leadership/Support (**NML)**

- National Command Authority Underground Facility (**NCA-UG**)
- National Command Authority Deep Underground Facility (**NCA-DUG**)
- National Military Leadership Facility (**NMLF**)
- National Military Leadership Facility Underground (**NMLF-UG**)
- National Military Leadership Facility Deep Underground (**NMLF-DUG**)
- Strategic Missile Threat and Strike Analysis Center (**SMAC**)

Intermediate-Echelon Strategic Leadership (**IESL)**

- SRF Headquarters (**SRF-HQ**)
- SRF Army Headquarters (**SRF-AHQ**)
- SRF Division Headquarters (**SRF-DHQ**)
- SRF Division Command Center (**SRF-DCC**)
- Strategic Missile Command and Launch Control Facility (**SMLCF**)
- Navy Fleet Headquarters (**NF-HQ**)
- SSBN (RPSKN) Flotilla and Division Headquarters (**SSBN-HQ**)
- Long Range Bomber Aviation Headquarters (**LRA-HQ**)

Intermediate-Echelon Non-Strategic Nuclear Leadership (**IENSL)**

- Military District Headquarters (**MD-HQ**)
- Navy Fleet Headquarters (**NF-HQ**)
- Flotilla and Division Headquarters, SSNs (**SSN-HQ**)
- Flotilla and Division Headquarters, Diesel Submarines (**SS-HQ**)
- Flotilla and Division Headquarters, Surface Ships (**SHIP-HQ**)
- Air Forces (Air Army and Military District Air Forces Headquarters) (**AFN-HQ**)
- Ground Forces (Independent Army, Combined-Arms Army, and Army Corps) Headquarters (**GF-HQ)**

Intermediate-Echelon Non-Nuclear Leadership (**IENNL)**

- Air Forces (Air Defense Army and Independent Air Defense Corps) Headquarters (**AF-HQ**)
- Airborne Forces Headquarters (**ABF-HQ**)
- Ground Forces Headquarters (**GF-HQ**)

Intelligence Leadership (**INTLL**)

- Intelligence Facility Headquarters (**INTEL-HQ**)

Telecommunications and Electronic Warfare (**TE**)

- Military Communication Station/Fixed Site (**MCSS**)
- Naval Communication Shore Station (**NCSS**)
- Fixed-Site VLF Stations for Submarine Communication (**VLF-S**)
- Low Frequency Transmitter (Non-Public) (**LF**)
- Very Low Frequency Transmitter (Non-Public) (**VLF**)
- Radio Transmission Tower (Unknown) (**UNKN**)

Satellite and Space Communication Systems (**SCS**)

Earth Station for Satellite Reception (**ES**)
Non-Communication Electronic Installations (**NCEI**)
Radar Installation (**RADAR**)
Radar Collocated with SAM Site (**RADAR-SAM**)
Missile Strike Warning System (Early Warning Radar) (**RADAR-MSWS**)
Space Surveillance Radar (**RADAR-SS**)
Air Traffic Control/Navigation Aid (**ATC/NAV**)
Meteorological Radar (**RADAR-MET**)
National-Level War Support Industry Leadership (**NWSL**)
Atomic Energy Leadership Institution (**AELI**)
Aerospace Leadership Institution (**ASLI**)
Defense Industry Leadership Institution (**DILI**)
Electronics and Telecommunications Leadership Institution (**ETLI**)
Chemical Industry Leadership Institution (**CILI**)
Shipbuilding Leadership Industry (**SLI**)
Internal Security Leadership Institution (**ISLI**)
Mining and Metallurgy Leadership Institution (**MMLI**)
National-Level Civilian Leadership/Support (**NCL**)
Foreign and Domestic Affairs Institution (**FDAI**)
Fuels and Energy Institution (**FEI**)
Construction and Labor Institution (**CLI**)
Federal Resources Institution (**FRI**)
Economic, Financial and Banking Institution (**EFBI**)
Communications, Media and Press Institution (**CMPI**)
Industrial Equipment Institution (**IEI**)
Transportation Institution (**TI**)
Food and Health Institution (**FHI**)
Judiciary Institution (**JI**)
Science, Technology and Education Institutions (**STEI**)
Leadership Policy, Planning and Training Institutes (**LPPTI**)
MOD Institute (**MODI**)
SRF Institute (**SRFI**)

War Support Industry-Urban/Industrial (**WSI**)
Strategic Missile Production Facilities (**SMPF**)
Missile Production Facility (**MPF**)
Missile Launcher Production Facility (**MLPF**)
Missile Component Production Facility (**MCPF**)
Strategic Aviation Production, Repair and Elimination Facilities (**SAPF**)
Strategic Aviation Factory (**SAF**)
Heavy Bomber Repair Facility (**HBRF**)
Heavy Bomber Conversion/Elimination Facility (**HBC&EF**)
Strategic Propulsion Production Facilities (**SPPF**)
Strategic Propulsion (Aircraft and Rocket Engines) Factory (**SPF**)

Naval Propulsion System Factory (**NPSF**)
Strategic Forces Research & Development Facilities (**SFR&DF**)
Missile Design Bureau (**MDB**)
Missile Design Institute (**MDI**)
Missile Launcher Design Bureau (**MLDB**)
Missile Testing Institute (**MTI**)
Space Design Bureau (**SDB**)
Naval Design Bureau (**NDB**)
Naval Research Institute (**NRI**)
Naval Shipyards (excludes major repair/overhaul yards) (**NY**)
Aviation Design Bureau (**AvDB**)
Aviation Research Institute (**AvRI**)
Propulsion and Guidance Technology Institute (**PTI**)
Propulsion (Aircraft and Rocket Engines) Design Institute (**PDI**)
Propulsion (Aircraft and Rocket Engines) Design Bureau (**PDB**)
Nuclear Weapons Support (other than strategic forces specific) (**NUC**)
Nuclear Warhead Research, Design and Testing (**NWD&T**)
Nuclear Warhead Production Enterprise (**NWPE**)
Nuclear Warhead Component Production (**NWCP**)
Nuclear Warhead Assembly, Disassembly and Maintenance (**NWAD&M**)
Basic and Applied Nuclear Research and Development (**B&ANR&D**)
Research/Test Reactor (**R/TR**)
a. Atomic Energy Associated Facilities Production and Storage
Fissile Material Storage Facility (**FMSF**)
Nuclear Service Ships-Icebreaker Fleet **(INSS)**
Nuclear Service Ships-Naval Fuel and Waste **(NSSNF\W)**
Nuclear Waste Storage Facility (**NWSF**)
Strategic Materials Production Facility (**SMPF**)
b. Atomic Energy Feed and Moderator Materials Production
Uranium Enrichment Facility (**UEP**)
Chemical Separation Facility (**CSF**)
Production Reactor (**PR**)
Uranium Mining and Milling (**UMM**)
Uranium Conversion Facility (**UCF**)
c. Nuclear Project Research, Design and Consulting
d. Nuclear Power Plant Construction and Support
Nuclear Reactor Manufacturer (**NRM**)
Nuclear Power Plant Support Facility (**NPPSF**)
e. Population Centers (Residences) of Nuclear Weapon Support Scientists
Population Center for NWRD&T Scientists (**PPL-NWRD&T**)
Population Center for Nuclear Weapon Production Enterprise (**PPL-NWPE**)
Population Center for AEF&P (**PPL-AEF&P**)
Satellite and Space Related Technologies (**SSRT**)
Space Launch Control Facility (**SLCF**)

- Missile Launch Complex (**MLC**)
- Payload Processing and Assembly Facility(**PPAF**)
- Satellite Design and Manufacturing Facility (**SDMF**)
- Space Research Institute (**SRI**)
- Commercial Space Service Organization (**CSSO**)

Conventional Forces Production Facilities (**CFPF**)

- SAM Production Facility (**SAM-PF**)
- Conventional Missile Production Facility (**CMPF**)
- Conventional Aviation Factory (**CAF**)
- Aviation Component Production Plant (**ACPP**)
- Navigation and Guidance Systems Production Facility (**NGPF**)
- Shipyards (**NY**)
- Armored Vehicle Production Facility (**ArVPF**)
- Conventional Ordnance Production Facility (**COPF**)

Conventional Forces Research and Development Facilities (**CFR&DF**)

- Aviation Design Bureau (**AvDB**)
- Aviation Research Institute (**AvRI**)
- Anti-Satellite Design Bureau (**ASDB**)
- Conventional Munitions Design Bureau (**CMDB**)
- Missile Design Bureau (**MDB**)
- Air Defense Systems Development (**ADSD**)
- Armored Vehicle Design Bureau (**ArVDB**)
- Armored Vehicle Research Institute (**ArVRI**)
- Conventional Ordnance Development Facility (**CODF**)

Electricity Power Generation, Transmission, and Control Facilities (**EP**)

- Electricity Transmission Substation (**ETS**)
- Geothermal Power Plants (**GPP**)
- Hydroelectric Power Plant (**HPP**)
- Nuclear Power Plant (**NPP**)
- Solar Power Plants (**SPP**)
- Thermal (and Other) Power Plant (**TPP**)
- Wind Generator Power Plants (**WPP**)

Transportation (supporting dispersal)

Oil and Gas Production, Transmission, and Storage Facilities

- Oil Refinery (**OR**)
- Oil/Gas Pipeline (**PL**)
- Oil Pipeline (**OPL**)
- Gas Pipeline (**GPL**)
- Gas and Oil Pipeline (**G&OPL**)
- Gas Compressor Station (**GCS**)
- Oil or Gas Pipeline Compressor Station (**O/GCS**)
- Underground Gas Storage Facility (**UGS**)
- Oil Storage Tank (**OST**)
- Oil Tanker Terminal (**OTT**)

- LNG Tanker Terminal (**LNGTT**)
- Natural Gas Processing Plant (**NGPP**)

Military Electronics Plants (**MEP**)

Industry, Aluminum (**IA**)

- Aluminum Production (**AP**)

Industry, Ferrous Metal Production (**FMP**)

- Pig Iron and Steel Production, Raw (**I&SP**)

Metals and Alloys Production Plants (**M&AP**)

- Graphite Applied R&D Institute (**GR&DI**)

Chemical Weapons Support Facilities (**CWSF**)

- Chemical Weapons Research Institute (**CWRI**)
- Chemical Weapons Production Facility (**CWPF**)
- Chemical Weapons Test Site (**CWTS**)
- Chemical Weapons Training Facility (**CWTF**)

Biological Weapons Support Facilities (**BWSF**)

- Biological Weapons Research Institute (**BWRI**)
- Biological Weapons Production/Standby Production Facility (**BWPF**)
- Biological Weapons Storage Site (**BWSS)**
- Biological Weapons Test Site (**BWTS**)
- Biological Weapons Component Production Facility (**BWCPF**)

Industrial Sector Government Agencies (**ISGA**)

Chemical Technology Institutes (**CTI**)

Naval Ship Facilities (**NSF**)

- Shipyards Used to Build and Overhaul Commercial Vessels **(NY)**
- Population Center Supporting Naval Ship Facilities (**PPL-NSF**)

Bridges (**BRDG**)

- Road Bridge, four lanes (**RDB4**)
- Road Bridge, two lanes (**RDB2**)
- Road Bridge, one lane (**RDB1**)
- Railroad, Bridge (**RRB**)
- Combined Railroad and 3 Lane Road Bridge (**R&RDB3)**

APPENDIX D
Nuclear Weapons Effects Equation List

NRDC has made use of two comprehensive sources of the equations that approximate the principal effects of a nuclear explosion: the "Help" files associated with the U.S. Department of Defense computer codes "BLAST" and "WE" (i.e., Weapons Effects). Most other general sources of information on the effects of nuclear explosion, for example Glasstone and Dolan's *The Effects of Nuclear Weapons*, only provide summary information and graphs. The equations from the BLAST and WE codes are given in Sections 1-7, below. We transcribed these nuclear weapons effects equations, corrected presumably typographic errors, and incorporated them into NRDC's nuclear conflict computer model. The simple fallout model presented in Section 5 below, is not that used in the Lawrence Livermore computer code KDFOC3, but is consistent with KDFOC3 within the scope of its much simpler phenomenology.

NRDC obtained versions 2.1 of BLAST and WE (both dated December 24, 1984) from the Internet site of the Federation of American Scientists (www.fas.org). They were produced under contract to the Defense Nuclear Agency (DNA—now the Defense Threat Reduction Agency) by Horizons Technology.

Section 8, below, provides a description of the methodology and formulas used to calculate damage probability to a target, given the target's physical vulnerability number and the parameters of the nuclear attack.

Contents:

1. Free-Air Equations for Blast

INPUT	OUPUT
ALT—Altitude (m); model limits: 0 to 25,000	SP—Altitude scaling factor for pressure
Y—Weapon Yield (kT); model limits: 0.1 to 25,000	SD—Altitude scaling factor for distance
RANGE—Range (m); model limits: (16 · Y3 · SD) to (4000 · Y3 · SD) where Y3 = $Y^{1/3}$ and SD is the altitude scaling factor.	ST—Altitude scaling factor for time
	C—Altitude-dependent speed of sound (m/s)
	PFREE—Free-air peak overpressure (Pa)
	QFREE—Free-air dynamic overpressure (Pa)
	TAFREE—Free-air time of arrival (s)

1.1 Altitude Scaling Factors (SP, SD and ST): For 0 ≤ ALT < 11,000, the altitude scaling subfactors are:

$$T = 1 - (2 \cdot 10^{9})^{-0.5} \cdot ALT$$
$$P = T^{5.3}$$
[1] and **[2]**

For 11,000 ≤ ALT < 20,000, the altitude scaling subfactors are:

$$T = 0.7535 \cdot [1 + (2.09 \cdot 10^{-7}) \cdot ALT]$$
$$P = 1.6^{0.5} \cdot [1 + (2.09 \cdot 10^{-7}) \cdot ALT]^{-754}$$
[3] and **[4]**

For 20,000 ≤ ALT the altitude scaling subfactors are:

$$T = 0.684 \times [1 + (5.16 \times 10^{-6}) \cdot ALT]$$
$$P = 1.4762 \times [1 + (5.16 \times 10^{-6}) \cdot ALT]^{-33.6}$$
[5] and **[6]**

The altitude scaling factors for pressure, distance and time are

$$SP = P \;\textbf{[7]};\quad SD = SP^{-1/3} \;\textbf{[8]};\quad ST = SD \cdot T^{-0.5} \;\textbf{[9]}$$

The altitude-dependent speed of sound is (rule of thumb: C increases 1.8% for each 10°C rise above 15°C):

$$C = (340.5)SD / ST \quad \textbf{[10]}$$

1.2 Overpressure, Dynamic Pressure, and Blast Wave Time of Arrival: Scale the range by the altitude scaling factor for distance and also the weapon yield:

$$R = (\mathrm{RANGE}) / (\mathrm{SD} \cdot Y^{1/3}) \quad \textbf{[11]}$$

The Defense Nuclear Agency (DNA) 1-kiloton free-air overpressure standard is given by the expression:

$$\Delta P_{DNA} = \frac{3.04 \cdot 10^{11}}{R^3} + \frac{1.13 \cdot 10^9}{R^2} + \frac{7.9 \cdot 10^6}{R\left(\ln\left[\frac{R}{445.42} + 3\exp\left[\frac{-1}{3}\sqrt{\frac{R}{445.42}}\right]\right]\right)^{1/2}} \quad \textbf{[12]}$$

The free-air peak overpressure is simply: $\Delta P_{FREE} = \Delta P_{DNA}$ **[13]**

The free-air peak overpressure at altitude is: $\Delta P_{FREE} = \Delta P_{FREE} \cdot SP$ **[14]**

The shock strength, xi, is: $xi = (\Delta p_{FREE} / 101,325) + 1$ **[15]**,

For $t=10^{-12}(xi)^6$ **[16]**, and $z = \ln(xi) - \frac{0.47 \cdot t}{100 + t}$ **[17]**,

The gamma, g_s, behind the shock is: $g_s = 1.402 - \frac{3.4 \cdot 10^{-4} \times z^4}{1 + 2.22 \cdot 10^{-5} \times z^6}$ **[18]**.

The shock mu, μ_s, is: $\mu_s = (g_s + 1)/(g_s - 1)$ **[19]**.

The mass density ratio across the shock front is: $n = \frac{1 + \mu_s \cdot xi}{5.975 + xi}$ **[20]**.

The free-air peak dynamic pressure is: $q_{FREE} = 0.5 \cdot \Delta p_{FREE}(n-1)$ **[21]**.

The free-air peak dynamic pressure at altitude is: $QFREE = (q_{FREE}) \cdot SP$ **[22]**.

The scaled free-air blast wave time of arrival is:

$$ta_{FREE} = \frac{R^2(6.7 + R)}{7.12 \cdot 10^6 + 7.32 \cdot 10^4 R + 340.5R^2} \quad \textbf{[23]}.$$

The free-air blast wave time of arrival, unscaled for altitude and weapon yield, is

$$TAFREE = (ta_{FREE}) \cdot ST \cdot Y^{1/3} \quad \textbf{[24]}$$

1.3 Dynamic Pressure from Overpressure

INPUT	OUPUT
ALT—Altitude (m); model limits: 0 to 25,000 PFREE—Free-air peak overpressure (Pa); model limits: $1374 \cdot 53 \cdot SP$ to $7.91151 \cdot 10^7 \cdot SP$ (SP = altitude scaling factor for pressure)	QFREE—Free-air dynamic pressure (Pa)

First, compute the altitude scaling factor for pressure (SP). Next, scale the free-air peak overpressure by SP:

$$\Delta P_{FREE} = (PFREE)/SP \quad \textbf{[25]}$$

Then, compute the free-air peak dynamic pressure, using Equations **[15]**–**[21]**

1.4 Rankine-Hugoniot Factors (Inputs and limits match FREE-AIR calculation dynamic pressure from overpressure if that calculation is selected; otherwise, they match overpressure, dynamic pressure and time of arrival from range)

INPUT	OUPUT
ALT—Altitude (m); model limits: 0 to 25,000 Y—Weapon Yield (kT); model limits: 0.1 to 25,000 RANGE—Range (m); model limits: $(16 \cdot Y3 \cdot SD)$ to $(4000 \cdot Y3 \cdot SD)$ where $Y3 = Y^{1/3}$ and SD is the altitude scaling factor	R_n—Normal reflection factor UC—Shock Mach number VC—Peak particle Mach number

If the inputs are weapon yield, altitude, and range then first do the equations described for the calculation **overpressure, dynamic pressure, and blast wave time of arrival;** otherwise, do the equations described for the calculation **dynamic pressure from overpressure;** the shock gamma is found in Equation **[18]** and the mass density ratio in Equation **[20]**.

The normal reflection factor is: $R_n = 2 + (g_s + 1)(n - 1)/2$ **[26]**.

The peak particle Mach number is: $VC = \left[\dfrac{\Delta p_{FREE}\left(1 - \dfrac{1}{n}\right)}{142,000} \right]^{0.5}$ **[27]**.

The shock front Mach number is: $UC = \dfrac{VC}{1 - \frac{1}{n}}$ **[28]**.

2. Air-Burst Equations for Blast

2.1 Overpressure, Dynamic Pressure, and Blast Wave Time of Arrival:

INPUT	OUPUT
Y—Weapon Yield (kT); model limits: 0.1 to 25,000	PAIR—Air-burst peak overpressure (Pa)
HOB—Height of Burst (m); model limits: 0 to (4,000 · Y3)	QAIR—Air-burst peak dynamic pressure (Pa)
GR—Ground range (m); model limits: LM to (4000 · Y3)	TAAIR - Air-burst time-of-arrival (s)

(where Y3 = $Y^{1/3}$ and LM = 0 if HOB = (25 · Y3); otherwise LM=20 · Y3)

(note: all the trig functions use radians)

The scaled ground range is: $\mathrm{SGR} = \mathrm{GR}/\mathrm{Y}^{1/3}$ **[1]**

The scaled height of burst is: $\mathrm{SHOB} = \mathrm{H}/\,\mathrm{Y}^{1/3}$ **[2]**

The scaled slant range is: $\mathrm{SR} = (\mathrm{SGR}^2 + \mathrm{SHOB}^2)^{1/2}$ **[3]**

The DNA Standard 1-kilton free-air overpressure is given by the expression:

$$\Delta p_{DNA} = \frac{3.04 \cdot 10^{11}}{SR^3} + \frac{1.13 \cdot 10^9}{SR^2} + \frac{7.9 \cdot 10^6}{SR\left[\ln\left[\dfrac{SR}{445.42} + 3 \times \exp\left(\dfrac{-1}{3} \times \sqrt{\dfrac{SR}{445.42}}\right)\right]\right]^{1/2}} \quad \textbf{[4]}$$

$$\alpha = \tan^{-1}(SHOB\ /\ SGR) \text{ (radians) } \textbf{[5]}.$$

The free-air peak overpressure is: $\Delta \mathrm{p}_{\mathrm{FREE}} = \Delta \mathrm{p}_{\mathrm{DNA}}$ **[6]**

$$T = \frac{340}{\Delta p_{FREE}^{0.55}}, U = \left(\frac{7782}{\Delta p_{FREE}^{0.7}} + 0.9\right)^{-1} \quad \textbf{[7]} \ \& \ \textbf{[8]}$$

$$W = \left(\frac{7473}{\Delta p_{FREE}^{0.5}} + 6.6\right)^{-1}, V = \left(\frac{647}{\Delta p_{FREE}^{0.8}} + W\right)^{-1} \quad \textbf{[9]} \ \& \ \textbf{[10]}$$

The regular/Mach region merge angle: $\alpha_m = \tan^{-1}\left(\dfrac{1}{T+U}\right)$(radians) **[11]**.

The width of the merge region: $\beta = \tan^{-1}\left(\frac{1}{T+V}\right)$ (radians) **[12]**.

$s = (\alpha - \alpha_m) / \beta;\ s_o = \text{maximum}[\text{minimum}(s, 1), -1]$ **[13]** & **[14]**

The regular/Mach region switching parameter, used to merge the Δp_{MACH} and the Δp_{REG} terms, is given by the expression: $\sigma = 0.5 \times \left[\sin\left(0.5 \cdot \pi \cdot s_o\right) + 1\right]$ **[15]**.

There are 3 cases:

for $\sigma = 0$, do Eqs. **[16]**–**[19]**
for $0 < \sigma < 1$, do Eqs. **[16]**–**[29]**
for $\sigma = 1$, do Eqs. **[20]**–**[29]**

Mach Reflection Region:
A = minimum[3.7–0.94 · ln(SGR), 0.7] **[16]**
B = 0.77 · ln(SGR) – 3.8 – 18/SGR **[17]**
C = maximum(A,B) **[18]**

Use SGR/$2^{(1/3)}$ in place of SR in Equation **[4]** and compute Δp_{DNA}:

$$\Delta p_{MACH} = \frac{\Delta p_{DNA}}{1 - C \times \sin(\alpha)} \quad \textbf{[19]}$$

Regular Reflection Region: The incident shock strength, xi, is: xi = Δp_{FREE}/101,325+1 **[20]**

$$t = 10^{-12} \cdot (xi)^6,\quad z = \ln(xi) - \frac{0.47 \times t}{100 + t} \quad \textbf{[21]}\ \&\ \textbf{[22]}$$

The gamma, g_s, behind the shock is: $g_s = 1.402 - \frac{3.4 \cdot 10^{-4} \times z^4}{1 + 2.22 \cdot 10^{-5} \times z^6}$ **[23]**

The shock mu, μ_s, is: $\mu_s = (g_s+1)/(g_s-1)$ **[24]**

The mass density ratio across the shock front is given by: $n = \frac{1 + \mu_s \times xi}{5.975 + xi}$ **[25]**

The normal reflection factor: $R_n = 2 + (g_s+1)(n-1)/2$ **[26]**; f = Δp_{FREE}/75,842 **[27]**

$$D = \frac{f^6\left(1.2 + 0.07 \cdot f^{0.5}\right)}{f^6 + 1} \quad \textbf{[28]};\quad \Delta p_{REG} = \Delta p_{FREE}\left[\left(R_n - 2\right)\sin^D(\alpha) + 2\right] \quad \textbf{[29]}$$

All three cases (i.e., for different values of σ) continue from here. Merging the regular and Mach region overpressure terms by means of the switching parameter, σ, gives the air-burst peak overpressure:

PAIR = $(\Delta p_{REG})\sigma + (\Delta p_{MACH})(1-\sigma)$ **[30]**

Use PAIR in place of Δp_{FREE} and do Equations **[20]** through **[25]**, $n_q = n$ **[31]**

The air-burst dynamic pressure [sin() uses radians] is:

$$QAIR = 0.5PAIR(n_q - 1)[1 - \sigma \sin^2(\alpha)] \quad \textbf{[32]}$$

To determine the air-burst time of arrival first requires the computation of the scaled Mach stem formation range: $x_m = SHOB^{2.5} / 5822 + 2.09 \cdot SHOB^{0.75}$ **[33]**

Then a scaling factor for the slant range is found: for SGR ≤ x_m, v = 1; for SGR > x_m, v = 1.26 – 0.26(x_m/SGR) **[34]**

Use the scaled range, R = SR/v, in the free-air time-of-arrival equation to compute the scaled air-burst time of arrival:

$$ta_{AIR} = \frac{R^2(6.7 + R)}{7.12 \cdot 10^6 + 7.32 \cdot 10^4 \times R + 340.5 \times R^2} \quad \textbf{[36]}$$

The unscaled air-burst time of arrival is then: TAAIR = $ta_{AIR}Y^{(1/3)}v$ **[37]**

2.2 Overpressure Total Impulse

INPUT	OUPUT
Y—Weapon yield (kT); model limits 0.1–25,000 HOB—height of burst (m); model limits 0–4000 · Y3 GR—Ground Range (m); model limits LM to 4000 · Y3 (where LM = 0 if HOB = 25 · Y3 m; otherwise LM = 20 · Y3 m)	IPTOTAL-Overpressure total impulse (Pa-s)

The scaled ground range is: SGR = maximum($GR/Y^{(1/3)}$,10^{-7}) **[1]**

The scaled height of burst is: SHOB = maximum($H/Y^{(1/3)}$,10^{-7}) **[2]**

The scaled slant range is: SR = $[SGR^2+SHOB^2]^{0.5}$ **[3]**

Compute the scaled Mach stem formation range and the air-burst time-of-arrival by doing Equations **[33]** through **[36]** in section 2.1, above, and then determine the peak air-burst overpressure by doing Equations **[4]** through **[32]** in section 2.1, above.

Next, calculate the following time-independent waveform, parameters:

$$s = 1 - \frac{1}{1 + \frac{1}{4.5 \cdot 10^{-8} \times SHOB^7}} - \frac{\left[\frac{5.958 \cdot 10^{-3} SHOB^2}{1 + 3.682 \cdot 10^{-7} (SHOB)^7}\right]}{\left[1 + \frac{(SGR)^{10}}{3.052 \cdot 10^{14}}\right]} \quad \textbf{[4]}$$

$$f = s\left[\frac{2.627(ta_{AIR})^{0.75}}{1 + 5.836 ta_{AIR}} + \frac{2341(ta_{AIR})^{2.5}}{1 + 2.541 \cdot 10^6 (ta_{AIR})^{4.75}} - 0.216\right] + 0.7076 - \frac{3.077}{10^{-4}(ta_{AIR})^{-3} + 4.367} \quad \textbf{[5]}$$

$$g = 10 + s\left[77.58 - \frac{154(ta_{AIR})^{0.125}}{1 + 1.375(ta_{AIR})^{0.5}}\right] \quad \textbf{[6]}$$

$$h = s\left[\frac{17.69 ta_{AIR}}{1 + 1803(ta_{AIR})^{4.25}} - \frac{180.5(ta_{AIR})^{1.25}}{1 + 99,140(ta_{AIR})^4} - 1.6\right] + 2.753 + \frac{56 ta_{AIR}}{1 + 1.473 \cdot 10^6 (ta_{AIR})^5} \quad \textbf{[7]}$$

The following factor is used in the computation of the overpressure positive phase duration:

$$t_o = \frac{\ln\left(1000 \cdot ta_{AIR}\right)}{3.77} \quad \textbf{[8]}$$

The scaled overpressure positive phase duration on the surface is given by:

$$dp_{SURF} = 10^{-3}\left[155 \exp\left(-20.8 \cdot ta_{AIR}\right) + \exp\left(-t_o^2 + 4.86 t_o + 0.25\right)\right] \quad \textbf{[9]}$$

The unmodified scaled overpressure positive phase duration is:

$$dp_{UNMOD} = dp_{SURF}\left[1 - \left[1 - \frac{1}{1 + 4.5 \cdot 10^{-8}(SHOB)^7}\right] \times \left[0.04 + \frac{0.61}{1 + \frac{\left(ta_{AIR}\right)^{1.5}}{0.027}}\right]\right] \quad \textbf{[10]}$$

The scaled overpressure positive phase duration for all heights of burst is:

$$dp_{\Delta p} = dp_{UNMOD}\left[1.16 \exp\left(\frac{-\left|\frac{SHOB}{0.3048} - 156\right|}{1062}\right)\right] \quad \textbf{[11]}$$

The equations on the following pages (Equations **[12]** through **[19]**) are primarily for double-peak overpressure waveforms. For single-peak waveforms the parameter dt is assumed to be zero.

If SGR < x_m or SHOB > 116 then skip to Equation **[20]**.

The approximation to the points where the two peaks are equal for

$$x_e = \frac{138.3}{1 + \dfrac{45.5}{SHOB}} \quad \textbf{[12]}$$

$$e = \max\left[\min\left(\left|\frac{SGR - x_m}{x_e - SGR}\right|, 50\right), 0.02\right] \textbf{[13]}, \quad w = \frac{0.583}{1 + \dfrac{2477}{SHOB^2}} \quad \textbf{[14]}$$

The first peak to second peak ratio is given by: d = 0.23 + w + 0.27e + e^5(0.5–w) **[15]**

$$a = (d-1)\left[1 - \frac{1}{1 + e^{-20}}\right] \quad \textbf{[16]}$$

The approximate time separation between the peaks is:

$$dt = \max\left[\frac{SHOB}{8.186 \cdot 10^5} \times \left[SGR - x_m\right]^{1.25}, 10^{-12}\right] \quad \textbf{[17]}$$

$$v_o = \frac{SHOB^6}{2445\left[1 + \dfrac{(SHOB)^{6.75}}{3.9 \cdot 10^4}\right]\left(1 + 9.23e^2\right)} \quad \textbf{[18]}, \quad c_o = \frac{\left[1.04 - \dfrac{1.04}{1 + \dfrac{3.725 \cdot 10^7}{(SGR)^4}}\right]}{(a+1)\left[1 + \dfrac{9.872 \cdot 10^8}{(SHOB)^9}\right]} \quad \textbf{[19]}$$

Using the time-independent parameters computed in the previous equations (Equations **[4]** through **[19]**), the following equations represent overpressure versus time. For any time t such that:
$ta_{AIR} \le t \le ta_{AIR} + dp_{\Delta p}$, first set the waveform positive phase duration: $dp = dp_{\Delta p}$. **[20]**

Then, using f, g and h from Equations **[5]**, **[6]** and **[7]** respectively, for any time t since the burst,

$$b = \left[f\left[\frac{ta_{AIR}}{t}\right]^g + (1-f)\left[\frac{ta_{AIR}}{t}\right]^h\right] \times \left[1 - \frac{t - ta_{AIR}}{dp}\right] \quad \textbf{[21]}$$

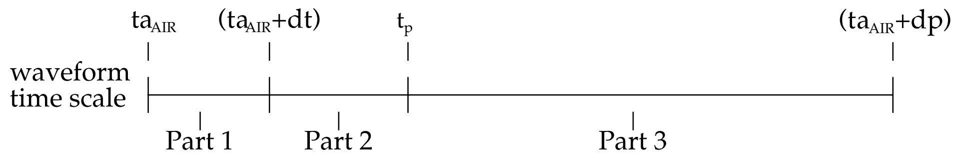
If SGR = x_m and SHOB = 116, then do Equations **[23]** through **[26]**; otherwise, the overpressure at time t is given by: Δp_t = (PAIR) · b **[22]**

$$g_a = \max\left[\min\left[\frac{t - ta_{AIR}}{dt}, 400\right], 0.0001\right] \textbf{[23]}, \quad v = 1 + \frac{v_o g_a^3}{g_a^3 + 6.13} \quad \textbf{[24]}$$

$$c = c_o\left[\frac{1}{g_a^{-7} + 0.923 g_a^{1.5}}\right] \times \left[1 - \left[\frac{t - ta_{AIR}}{dp}\right]^8\right] \quad \textbf{[25]}$$

The overpressure at time t is then given by: Dpt = (PAIR)(1+a)(b · v + c) **[26]**

The overpressure total impulse is now found by numerically integrating the above equations (either Equations **[21]** and **[22]**, or Equations **[21]**, and **[23]** through **[26]**). The technique used by the programs BLAST and WE to do the numerical integration is the Guass-Legendre Quadrature. The waveform is partitioned into 2 or 3 parts (depending on whether the waveform is single-peaked or double-peaked). The time parts are as illustrated below:



where $t_p = (13ta_{AIR} + dt + dp)/14$. If the waveform is single-peaked assume dt is zero and ignore Part 1. Part 1 is numerically integrated using a 4-point Gauss-Legendre Quadrature. Parts 2 and 3 are each integrated using an 8-point Gauss-Legendre Quadrature with time in log-space [that is, ln(t) is the independent variable, not t]. The overpressure total impulse is then

IPTOTAL = (sum)$Y^{1/3}$ **[27]**, where sum = Gauss-Legendre Quadrature sum.

2.3 Dynamic Pressure Total Impulse

Y—Weapon yield (kT); model limits 0.1–25,000

HOB—Height of burst (m); model limits 0 – 750 · Y3

GR—Ground range (m); model limits LM to 4000 · Y3

LM = maximum(1.3 · XM, 80 · Y3), XM · Mach stem formation range

IQTOTAL—Dynamic pressure total impulse (Pa-s)

(All trig functions use radians)

The dynamic pressure waveform is a function of the overpressure waveform; consequently, many of the equations from section 2.2 OVERPRESSURE TOTAL IMPULSE are needed. To begin, do Equations **[1]** through **[8]** from that section.

Then, $SHOB_o$ = SHOB/0.3048 **[1]**, SGR_o = SGR/0.3048 **[2]**, $SHOB_x$ = abs($SHOB_o$ – 200) + 200 **[3]**, $SGR_x = SGR_o - 1000$ **[4]**, $dp_o = 0.3 + 0.42 \cdot \exp(-SHOB_x/131)$ **[5]**

$$dp_x = \begin{vmatrix} dp_o + 4.4 \cdot 10^{-5} SGR_x, SGR_x > 0 \\ dp_o + SGR_x\left[\frac{1}{2361} - \frac{\left|SHOB_x - 533\right|^2}{7.88 \cdot 10^7}\right], SGR_x \le 0 \end{vmatrix} \quad \textbf{[6]}$$

The scaled dynamic pressure positive phase duration is:

$$dp_q = \begin{vmatrix} dp_x, SHOB_0 \geq 200 \\ dp_x\left[1 + 0.2\sin\left(SHOB_o \cdot \pi / 200\right)\right], SHOB_o < 200 \end{vmatrix} \quad \textbf{[7]}$$

where the sin() argument is in radians. Next, the waveform parameters in Equations **[12]** through **[19]** from section 2.2 OVERPRESSURE TOTAL IMPULSE need to be computed. The remaining dynamic pressure waveform parameters appear below:

$$\delta_o = \max\left[\frac{\left(SHOB_o\right)^{1.52}}{16,330} - 0.29, 0\right] \quad \textbf{[8]}$$

The dynamic pressure waveform decay exponent is:

$$\delta = 2.38\exp\left[-7 \cdot 10^{-7}\left|SHOB_o - 750\right|^{2.7} - 4 \cdot 10^{-7}\left(SGR_o\right)^2\right] + \delta_o \quad \textbf{[9]}$$

The dynamic pressure waveform multiplier is: $q_o = 0.5\{1 - \sigma[\sin(\sigma)]^2\}$ **[10]**
where σ is from Equation **[15]**, and α is from Equation **[5]** (both equations are found in section 2.1 PEAK PRESSURES & BLAST WAVE TIME OF ARRIVAL) and sin() is in radians.

Using the time-independent parameters computed in the previous equations (Equations **[12]** through **[19]** from the HELP section OVERPRESSURE TOTAL IMPULSE), the following equations represent dynamic pressure versus time. For any time t such that: $ta_{AIR} \leq t \leq ta_{AIR} + dp_q$, first set the waveform positive phase duration: $dp = dp_q$. **[20]** Next, do Equations **[21]** through **[26]** from section 2.2 OVERPRESSURE TOTAL IMPULSE as needed to compute Δp_t.
Do Equations **[20]** through **[25]** from section 2.1 PEAK PRESSURES & TIME-OF-ARRIVAL using Δp_t in place of Δp_{FREE}. $n_q = n$ **[12]**.
The dynamic pressure at time t is given by:

$$q_t = 0.5\Delta p_t\left(n_q - 1\right)\left[\frac{\Delta p_t}{PAIR}\right]^{\delta} \quad \textbf{[13]}$$

The dynamic pressure total impulse is not found by numerically integrating Equation **[13]** above (which reuires Equations **[21]** an **[22]**, or Equations **[21]**, and **[23]** through **[26]** from section 2.2 OVERPRESURE TOTAL IMPULSE).

2.4) Overpressure Partial Impulse

Y—Weapon yield (kT); model limits 0.1–25,000
HOB—Height of burst (m); model limits 0–4000 · Y3
GR—Ground range (m); model limits LM–4000 · Y3
TIME—Time after time of arrival (s); model limits 0-DPP
where LM = 0 if HOB = 25 Y3 (meters); otherwise LM = 20 Y3 (meters); DPP = overpressure positive phase duration
IPPART—Overpressure partial impulse (Pa-s)

The equations needed to compute the overpressure partial impulse are amost idential to those used in the calculation of overpressure total impulse (whose equations are found in section 2.2 OVERPRESSURE TOTAL IMPULSE). The only difference is that the upper limit for the integration of the waveform has changed. The upper limit should be: $ta_{AIR} + (TIME) / Y^{1/3}$ **[1]**

The overpressure partial impulse is given by : $IPPART = (sum)Y^{1/3}$ **[2]**, where sum = Gauss-Legendre Quadrature sum.

2.5 Dynamic Pressure Partial Impulse

Y—Weapon Yield (kT); model limits 0.1–25,000
HOB—Height of burst (m); model limits 0–750 Y3
GR—Ground range (m); model limits LM-4000 Y3
TIME—Time after time of arrival (s); model limits 0-DPQ
 where LM = maximum(1.3 XM, 80 Y3), XM = Mach stem formation range, and
 DPQ = dynamic pressure positive phase duration
IQPART—Dynamic pressure partial impulse (Pa-s)

The equations needed to compute the overpressure partial impulse are almost identical to those used in the calculation **dynamic pressure total impulse** (whose equations can be found in section 2.2 DYNAMIC PRESSURE TOTAL IMPULSE). The only difference is that the upper limit for the integration of the waveform has changed. The upper limit should be:
$ta_{AIR} + (TIME) / Y^{1/3}$ **[3]**

The dynamic pressure partial impulse is given by: $IQPART = (sum)Y^{1/3}$ **[4]**, where sum = Gauss-Legendre Quadrature sum.

2.6 Time-Dependent Overpressure: Inputs and limits are the same as the calculation-overpressure partial impulse.
PT—Time-dependent overpressure (Pa)
The time-dependent overpressur is computed as in the calculation **overpressure total impulse.** Those equations can be found in section 2.2 OVERPRESSURE TOTAL IMPULSE). It is not necessary to do the equations related to the integration of the overpressure waveform.

The time-dependent overpressure for the given time, t = (TIME)/$Y^{1/3}$ **[5]**
is found in Equation **[22]** (for single-peak waveforms) or Equation **[26]** (for double-peak waveforms) in section 2.2 OVERPRESSURE TOTAL IMPULSE.
PT = Δp_t **[6]**

2.7 Time-Dependent Dynamic Pressure: Inputs and limits are the same as the calculation dynamic pressure partial impulse.

QT—Time-dependent dynamic pressure (Pa)

The time-dependent dynamic pressure is computed as in the calculation dynamic pressure total impulse (whose equations can be found in the HELP section DYNAMIC PRESSURE TOTAL IMPULSE). It is not necessary to do the equations related to the integration of the dynamic pressure waveform.
The time-dependent dynamic pressure for a given time, $t = (TIME)/Y^{1/3}$ **[7]** is found in Equation **[13]** in section 2.3 DYNAMIC PRESSURE TOTAL IMPULSE.
$QT = q_t$ **[8]**

2.8 Overpressure Positive Phase Duration
Y—Weapon yield (kT); model limits 0.1–25,000
HOB—Height of burst (m); model limits 0–4000 Y3
GR—Ground range (m); model limits LM-4000 Y3
where LM = 0 if HOB = 25 Y3 m; otherwise LM = 20 Y3 (meters).
DPP—Overpressure positive phase duration (s)

First, compute the scaled ground range (SGR) and scaled height of burst (SHOB) as shown in Equations **[1]** and **[2]** from section 2.2 OVERPRESSURE TOTAL IMPULSE. The scaled overpressure positive phase duration can then be computed using Equations **[8]** through **[11]** from the same section. The unscaled overpressure positive phase duration is given by: $DPP = \left(dp_{\Delta p}\right)Y^{1/3}$ **[9]**.

2.9 Dynamic Pressure Positive Phase Duration
Y—Weapon yield (kT); model limits 0.1–25,000
HOB—Height of burst (m); model limits 0–750 Y3
GR—Ground range (m); model limits LM-4000 Y3
where LM = maximum(1.3 XM, 80 Y3), and XM = Mach stem formation range
DPQ—Dynamic pressure positive phase duration (s)

First, compute the scaled ground range (SGR) and scaled height of burst (SHOB) as shown below. The scaled ground range is: $SGR = \text{maximum}(GR/Y^{1/3}, 10^{-7})$ **[10]**
The scaled height of burst is: $SHOB = \text{maximum}(H/Y^{1/3}, 10^{-7})$ **[11]**
The scaled dynamic pressure positive phase duration can then be computed using Equations **[1]** through **[7]** from section 2.3 DYNAMIC PRESSURE TOTAL IMPULSE. The unscaled dynamic pressure positive phase duration is given by:
$DPQ = (dp_q)Y^{1/3}$ **[12]**.

2.10 Mach Stem: Formation Range and Triple Point Height
Y—Weapon yield (kT); model limits 0.1–25,000
HOB—Height of burst (m); model limits 0–800 Y3
GR—Ground range (m); model limits LM-4000 Y3
where $Y3 = Y^{1/3}$, LM = maximum(XM, 20 · Y3), XM = Mach stem formation range
XM—Mach stem formation range (m)
HTP—Height of triple point (m)

The scaled ground range is: $SGR = GR/Y^{1/3}$ **[1]**. The scaled height of burst is: $SHOB = H/Y^{1/3}$ **[2]**. The scaled Mach stem formation range is: $x_m = SHOB^{2.5}/5822 + 2.09SHOB^{0.75}$ **[3]** and the unscaled formation range is: $XM = x_m Y^{1/3}$ **[4]**.

$$S = \left(5.98 \cdot 10^{-5} SHOB^2 + 3.8 \cdot 10^{-3} SHOB + 0.766\right)^{-1} \textbf{ [5]}$$

$$h = 0.9x_m - 3.6 \cdot SHOB \textbf{ [6]}.$$

The unscaled height of the triple point is:

$$HTP = S\left\{h + \left[h^2 + \left(SGR - 0.9x_m\right)^2 - x_m^2 / 100\right]^{0.5}\right\} \times Y^{1/3} \textbf{ [7]}$$

3. Initial Radiation Calculations: Total Dose, Neutron Dose, and Gamma Dose

Y—Yield(kT); model limits 0.1–25,000

AIR—Air Density Ratio; model limits $0.6 \leq AIR \leq 1.0$

H—Height of burst (m); model limits $1.5/AIR \leq H \leq 10{,}000/AIR$

GR—Ground range (m); model limits $x/AIR \leq GR \leq y/AIR$

where, for neutron and secondary gamma doses doses, $x=[\text{maximum}(0,10^4 - H^2)]^{1/2}$; for all other doses,

$x = \{\text{maximum}[0,(150\ \text{maximum}\{1,Y^{1/3}\}^2 - H^2]\}^{1/2}$; $y = (10^8 - H^2)^{1/2}$

FF—Fission fraction; model limits $0.0 \leq FF \leq 1.0$

WT—Weapon type; model limits 1–13

N—Neutron component of total dose (rad(tis))

SG—Secondary-gamma component of total dose (rad(tis))

FFG—Fission-fragment-gamma component of total dose (rad(tis))

TD—Total dose (rad(tis))

DS—Total dose (rad(sil))

N/G—Neutron-to-gamma dose ratio

(all trig functions use radians)

The component doses are:

$N = D_n C_n YAIR^2$ **[1]**

$SG = D_g C_g YAIR^2$ **[2]**

$FFG = D_{ff} C_f H_e Yff$ **[3]**

And the total dose (in tissue) is the sum of components,

$TD = N + SG + FFG$ **[4]**

Common factors: The slant range is: $SR = (GR^2 + H^2)^{1/2}$ **[5]**

Air-density scaled slant range: $SR_o = (AIR)(SR)$ **[6]**

Air-density scaled height of burst: $H_o = (AIR)(H)$ **[7]**

Height of burst switching parameter for C_g and C_n: $s = \text{minimum}\{1,\text{maximum}[-1, (H_o - 277)/50]\}$ **[8]**

$\sigma = 0.5\ [1+\sin(s\ \pi/2)]$ **[9]**

Neutron Dose Yield-scaled factor: $D_n = [a/(SR_o)^c]\exp[b(SR_o)]$ **[10]**

where $a = 10^6a'$, $b = -(500+b')/105$, $c = 1+c'/1000$ **[11]**, **[12]**, and **[13]**

and the coefficients a′, b′ and c′ for D_n are as follows:

WT	a′	b′	c′
1 & 3	253	71	138
2	98	49	225
4, 7 & 11	394	31	261
5	347	52	147
6	177	67	152
8	450	24	323
9	753	–13	482
10	272	13	933
12	300	–13	492
13	1431	–2	63

Secondary-Gamma Dose Yield-Scaled Factor: $D_g = [a/(SR_o)^c]\exp[b(SR_o)^d]$ **[14]**
where for WT = 10: a = 13.5, b = –0.344, c = –1.537, d = 0.5173 **[15–18]**
and for all other WT's: $a = \text{antilog}_{10}(a'/100)$, **[19]** $b = -(193+b')/10^4$, **[20]**
c = c′/1000, **[21]** d = 0.8 **[22]**
and the coefficients a′, b′ and c′ for D_g are as follows:

COEFFICENTS FOR D_g			
WT	a′	b′	c′
1	357	32	–188
2	605	0	793
3 & 6	433	27	68.8
4, 5, 7, 9, & 11	542	14	439
8	490	18	297
12	604	7	633
13	722	8	651

Fission-fragment-gamma Dose Yield-scaled factor:

$$D_{ff} = 1.42 \cdot 10^7 / \left(SR_x\right)^{0.9516} \times \exp[-\left(SR_x\right)^{0.774} / 32.7] \qquad \textbf{[23]}$$

where $SR_x = Sgn(SR - 140)|SR - 140|^P + 140$ **[24]**

Sgn(x) = –1, for x < 0; 0 for x = 0; +1 for x > 0 **[25]**
and p = AIR(0.264-AIR/12.6) + 0.815 **[26]**
Secondary Gamma Dose Height of Burst Correction Factor: $C_g = a + \exp\{b+c[1-\exp(4 \times 10^{-5}(SR_o)]\}$ **[27]**
where $H_x = \text{minimum}(1000, H_o)$; for WT = 13, $C_{gmax} = 1.1$, $a_o = 0.002$ **[28–30]**

$b = -2.12 + \exp(H_x^{0.903} / 204) + 0.977(1 - \sigma)$ **[31]**

and for all other WT's: $C_{gmax} = 1$, $a_o = 0.0035$, **[32–33]**

$b = b'/100 + \exp[H_x^{0.88} / (b''+192)] + (1 - \sigma)\pi / 6$ **[34]**

and then for all WT's: $x = 0.9 - a'/1000$, $t_1 = a_o H_o^x$,

$t_2 = a_o 277^x + 0.00011 H_o^{(1+a''/100)}$ **[35–37]**

a = minimum[C_{gmax}, 0.31 + (1 – σ)t_1 + σt_2], c = c′ + (σ/c″)maximum(0,H_x–277)$^{1.4}$ **[38-39]**

and the coefficients a′, a″, b′, b″, c′ and c″ for C_g are as follows:

COEFFICENTS FOR C_g						
WT	a′	a″	b′	b″	c′	c″
1, 3 & 4	59	9	8	5	98	108
2, 6 & 10	61	9	34	13	108	142
5	50	11	–25	1	90	92
7 & 12	42	12	–4	2	100	93
8, 9 & 11	44	11	–43	0	86	87
13	–87	12	0	0	62	84

Fission fragment Gamma Dose Correction Factor: Based on ATR 4.1 DTA as modified by SAI for yields below 1 MT: The yield-scaled height of burst:
SH = minimum(H/$Y^{1/3}$, 250), s_f = sin[1.16 log(Y)–1.39], z = (log(Y)–1.4)/3.5 **[40–42]**

$$C_f = 0.5\left[z + \left(z^2 + 0.044\right)^{1/2}\right](AIR)\left[1 - \frac{SH}{125}\right] + 0.038Log(Y) - 0.22 +$$

[43]

$$\left[\frac{GR}{1000} - 0.65\log(Y) - 0.4\right]0.075\left[s_f + 2\left|s_f\right|(AIR - 0.9)\right]$$

C_f = antilog$_{10}$(C_f). **[44]**

Fission Fragment Gamma Dose Hydrodynamic Enhancement Factor: For Y less than 1 do only Equation **[45]** otherwise do Equations **[46–52]**:
H_e = 1 **[45]**. Otherwise for Y greater than or equal to 1: A_H = antilog$_{10}$[a(log$_{10}$Y)^b] **[46]**
where a = 0.1455 AIR – 0.0077 **[47]**; b = 2.55 – 0.35 AIR **[48]**
B_Y = 1–[1+c(log$_{10}$Y)$^{2.6}$]exp[–d(log$_{10}$Y)$^{2.6}$] **[49]**, where c = 0.05875 AIR+0.004 **[50]**

$$d = 0.04AIR - 0.03Sgn(AIR - 0.6)\left|AIR - 0.6\right|^{1.3}$$ **[51]**

H_e = minimum{$A_H$exp[B_Y(SR/1000)], exp[(–0.26+2.563 AIR)(SR/1000)]} **[52]**

Neutron Dose Height of Burst Correction Factor: $C_n = a + b\exp\left[-c\left(SR_o^d\right)\right]$ **[53]**
where

$$t_1 = 0.205 + 2.2 \cdot 10^{-3} H_o^{0.839}, t_2 = 0.4514 + H_o^{1.636} / 637^2,$$

a = minimum[1,(1–σ)t_1+σt_2] **[54–56]**

$$t_3 = 0.388 + 0.116H_o^{0.27}, t_4 = 0.9176 + H_o^{3.726} / 1.78 \cdot 10^{10}, b = (1 - \sigma)t_3 + \sigma t_4$$ **[57–59]**

$$c = 8 \cdot 10^{-4} + 0.0728 / \left(H_o^{1.23} + 23.6\right), d = 0.9$$ **[60–61]**

If H_o is greater than 1 do Equation **[62]**: d = 0.9+ln(H_o)/25 **[62]**

The neutron dose/gamma-ray dose ratio, N/G = N/[(SG) + (FFG)] **[63]**

The total dose (in silicon) is: $DS = FFG + SG + f_n N$ **[64]**

for WT not 10 nor 13, $f_n = 0.015$ **[65]**, for WT = 10 $f_n = \exp[(SR)/800]/250$ **[66]**,
for WT = 13 $f_n = \exp[-(SR)/234.7]/20 + \exp[-(SR)/4329]/25$ **[67]**

4. Thermal Equations

If the quantity calculated is *transmittance*, then it includes both direct and scattered thermal radiation.

Calculation: Thermal Fluence

Y—Yield (kT); model limits 0.1–25,000
H—Height of burst (m); model limits $0\text{–}1500 \cdot Y^{1/3}$
GR—Ground range (m); model limits $x \neq GR \leq 2200 \cdot Y^{1/3}$
  where $x = \max\{[(100 \cdot Y^{1/3})^2 - H^2],0\}^{1/2}$
VIS—Visibility (m); model limits $10{,}000 \leq VIS \leq 80{,}000$
FLUE—Thermal fluence to ten times the time of second maximum of the thermal output (cal/cm^2)

The slant range is: $SR = (H^2+GR^2)^{1/2}$ **[1]**, The transition height of burst is $H_T = 4 \cdot Y^{1/3}$ **[2]**.

Surface Burst Equations: $A_1 = 0.32\left[1 - \exp\left(-12Y^{-VIS/17000}\right)\right]$ **[3]**

$B_1 = -(\log_{10}Y)^2/275 + 0.0186\log_{10}Y - 1/40$ **[4]**, $A_2 = [(30 \cdot Y^{-0.26})^4 + 1350]^{-1/4}$ **[5]**,
$B_2 = -(1.457/VIS + 9.3 \cdot 10^{-6})$ **[6]**

$F_S = A_1\exp(B_1\ SR) + A_2\exp(B_2 \cdot SR) + 0.006$ **[7]**

Air Burst Equations: $A_3 = H^{3/2}/(5 \cdot 10^7) + 97/(281 + Y^{1/2})$ **[8]**,
$B_3 = (0.139/H)[\exp(-8 \cdot H/VIS) - 1]$ **[9]**

$F_A = A_3\exp(B_3 \cdot SR)$ **[10]**

Transition Region Equations: For $H \geq H_T$, $F = F_A$, for $0 \leq H < HT$,
$F = F_A(H/H_T) + F_S(1 - H/H_T)$ **[11]**

$Q = 8 \cdot 10^6 Y/SR^2$ **[12]**

5. Fallout Equations

5.1 One-Hour Dose Rate and Debris Arrival Time

Y—Yield (kT); model limits 0.1–25,000
H—Height of Burst (m); model limits 0–4000
DW—Downwind ground range (m); model limits $0\text{–}10^6$
CW—Crosswind ground range (m); model limits 0–40,000

W—Effective wind speed (kn); model limits 1–40
SY—Crosswind shear (kn/kft); model limits 0–10
FF—Fission fraction; model limits 0–1
DH+1—One-hour dose rate (roentgen/hr)
T0—Debris arrival time (hours)
MBD-Max. biological dose (roentgen)
$\hat{H} = H / 0.3048$ **[1]**, for $\hat{H} = 0$, do Equation **[2]**: AF = 1 **[2]**. For $\hat{H} > 0$, do Eqs. **[3]** and **[4]**:
$z = 0.01 \cdot \hat{H} / Y^{0.4}$ **[3]**, For $z > 1$, AF = 0. **[4a]** If $z = 1$, $AF = 0.5(1-z)^2(2+z) + 0.001 \cdot z$ **[4b]**
$Y_m = Y/1000$ **[5]**

Cloud radius (nautical miles), for Y = 1: $\sigma_0 = Y_m^{1/3} \exp\left(0.56 - \frac{3.25}{\left[4 + \left(\ln Y_m + 5.4\right)^2\right]}\right)$

[6a],

and for Y < 1, $\sigma_D = 0.1 \cdot Y^{0.2665}$ **[6b]**

Cloud height (kilofeet), for Y = 1:
$h_0 = 44 + 6.1 \ln Y_m - 0.205 \cdot \left[\ln Y_m + 2.42\right] \cdot \left|\ln Y_m + 2.42\right|$ **[7a]**.
For Y < 1, $h_0 = 6 \cdot Y^{0.25}$ **[7b]**.

Cloud duration (hours):
$T = 1.057 \cdot h_0\left(0.2 - h_0 / 1440\right)\left[1 - \exp\left(-h_0^2 / 625\right) / 2\right]$ **[8]**
Cloud thickness (kilofeet): $\sigma_h = 0.18 \cdot h_0$ **[9]**

Effective particle distance (nautical miles): $L_0 = W \cdot T\iota$ **[10]**

Change in fallout distribution: $\sigma_x = \sigma_0\left[\left(L_0^2 + 8\sigma_0^2\right) / \left(L_0^2 + 2\sigma_0^2\right)\right]^{1/2}$ **[11]**

A modified form of L_0: $L = \left[L_0^2 + 2\sigma_x^2\right]^{1/2}$ **[12]**

Constant for symmetry, $N = \left(L_0^2 + \sigma_x^2\right) / \left(L_0^2 + 0.5\sigma_x^2\right)$ **[13]**

Downwind distance (nautical miles), d = DW/1853 **[14]**

Crosswind distance (nautical miles), c = CW/1853 **[15]**

Area reduction factors: $\alpha_1 = (1 + 0.001 \cdot h_0 \cdot W/\sigma 0) - 1$ **[16]**
$\alpha_2 = \left\{1 + \frac{0.001 h_0 W}{\sigma_0\left[1 - \Phi(2d / W)\right]}\right\}^{-1}$ **[17]**

Where $\phi(u)$, the cumulative normal distribution function, is approximated by the expression: $\phi(u) = [1 + \exp(-1.5976u - 0.0706\, u^3)]^{-1}$ **[18]**

The crosswind spread parameter, $\sigma_y = \left\{\sigma_0^2 R + 2(P\sigma_x)^2 + (PQL_0)^2\right\}^{1/2}$ **[19]**

where $P = (SY)T_i\sigma_h/L$ **[20]**, $Q = |d + 2\sigma_x| / L$ **[21]**, and R = minimum[4,1+8Q] **[22]**

The crosswind transport function: $F_1 = \dfrac{\exp\left[-\left(c / \left\{\alpha_2\sigma_y\right\}\right)^2 / 2\right]}{\sigma_y[2\pi]^{1/2}}$ **[23]**

The downwind transport function: $F_2 = \Phi\left(\dfrac{L_0 d}{L\alpha_1\sigma_x}\right)$ **[24]**

The deposition function, $F_3 = \dfrac{\exp\left(-\left|\dfrac{d}{L}\right|^N\right)}{L \cdot \Gamma\left(1 + \dfrac{1}{N}\right)}$ **[25]**, where the gamma function is

approximated by the expression: $\Gamma(u) = 0.994 - 0.446(u-1) + 0.455(u-1)^2$, $1 \le u \le 2$ **[26]**

$F = F_1 \cdot F_2 \cdot F_3$ **[27]**

The one-hour dose rate, DH+1 = 1,510 · (Y) · (FF) · (AF) · (F) **[28]**

The debris arrival time, $T0 = \left\{0.25 + \dfrac{(L_0 Q T_i)^2 + 2\sigma_x^2}{L_0^2 + 0.5\sigma_x^2}\right\}^{1/2}$ **[29]**

The maximum biological dose can be found using the equations on the following pages:

5.2 Maximum Biological Dose Rate

T0—Debris arrival time (hr); model limits 0.5–550

DH+1—One-hour dose rate (roentgen/hr); model limits $0–10^9$

MBD—Max. biological dose (roentgen)

$z = \ln(T_0)$ **[30]**, $MBD = (DH + 1)\left(2.737 - 0.7809 z_0 + 2 z_0^2 / 29 - z_0^3 / 617\right)$ **[31]**

5.3 t-Hour Dose Rate Given One-Hour Dose Rate

T—measurement time (hr); model limits 0.1–5000

DH+1—One-hour dose rate (roentgen/hr); model limits 0–10

DT—t-hour dose rate (roentgen/hr)

The t-hour dose rate: $DT = (DH+1)T^{-1.2}$ **[32]**

5.4 One-Hour Dose Rate Given t-Hour Dose Rate

T—Measurement time (hr); model limits 0.1–5000

DT—t-hour dose rate (roentgen/hr); model limits 0–10^9

DH+1—One-hour dose rate (roentgen/hr)

The one-hour dose rate, $DH+1 = (DT)T^{1.2}$ **[33]**

5.5 Total Fallout Dose

TI—Initial exposure time (hr); model limits 0.1–5000

TEXP—Exposure duration (hr); model limits 0 to (5000-TI)

DH+1—One-hour dose rate (roentgen/hr); model limits 0–10^9

FD—Total fallout dose (roentgen)

The fallout total dose: $FD = 5(DH+1)\left[TI^{-0.2} - (TI + TEXP)^{-0.2}\right]$ **[34]**

6. Cratering Equations

Definitions:

Fallback: Material that was lifted or thrown out by the explosion and has fallen back within the true crater

True crater: the approximate boundary between the fallback material and the rupture zone (the shape of the true crater is disguised by the fallback)

Apparent crater: the crater that is visible on the surface, the dimensions being measured between fallback and the original ground surface elevation

Above-Surface Burst: $HOB/Y^{1/3} > 0$ (Bursts of most significance to cratering are for $HOB < Y^{1/3}(3\ m/kT^{1/3}.)$; **Contact Burst:** HOB ~ 0.5 m; **Surface Burst:** HOB = 0.; **Shallow-Buried Burst:** $0 > HOB/Y^{1/3} > -5m/kT^{1/3}$; **Deep-Buried Burst:** $HOB/Y^{1/3} < 5\ m/kT^{1/3}$.

INPUT	OUPUT
Y—Yield (kT); model limits 0.1-25,000	SV—Scaled apparent crater volume (m^3)
HOB—Height of Burst; model limits $-40Y^{1/3}$ to $3Y^{1/3}$	V—Apparent crater volume (m^3)
GR—Ground range from burst point (m); model limits 1.8*CR ≤ GR ≤ 10,000 (CR is the apparent crater radius	CR—Apparent crater radius (m)
T1—Thickness of material layer #1 (m); model limits 0-1000	CD—Apparent crater depth (m)
T2—Thickness of material layer #2 (m); model limits 0-1000	EJ—Depth of the ejecta or debris (m)
T3—Thickness of material layer #3 (m)	
M1, M2 & M3—Geologic material types: 1=Dry Soil, 2=Wet Soil, 3=Dry Soft Rock, 4=Wet Soft Rock, 5=Hard Rock	

6.1 Crater Dimensions and Ejecta Thickness

The first scaled depth of burial is: $S_1 = -HOB/Y^{1/3}$ **[1]**.

The second scaled depth of burial is: $S_2 = -HOB/Y^{\alpha}$ **[2]**, where α is the volume scaling exponent.

The volume scaling exponent, α, varies with material type and burst location. The burst location falls into three regions: air burst, near-surface buried, and deeply buried. The yield also falls into three regions: 1 kT or less, 1 to 20 kT (interpolation region), and greater than 20 kT. Weapons with high radiative output use the 20 kT scaling exponent for all yields. Normal radiative output weapons use an interpolation in the 1 to 20 kT region.

For all material types, and for Y < 1 kT:

$$\alpha_1 = \begin{vmatrix} 1/3, \textit{ for } -3 \le S1 \le 0.15 \\ 0.2946 + \dfrac{\exp\left[-(S1)\log_{10}(583)\right]}{305^{1/2}}, \textit{ for } -0.15 \le S1 \le 5 \\ 1/3.4, \textit{ for } 5 \le S1 \end{vmatrix} \quad \textbf{[3]}$$

For all material types except dry Soil, and for Y > 20 kT: $\alpha_{20} = 1/3.4$ **[4]**

For dry soil, and for Y > 20 kT:

$$\alpha_{20} = \begin{vmatrix} 1/3.1, \textit{ for } -3 \le S1 \le 0 \\ 1/\left[3.4 - 0.3\exp(-2.2 \cdot S1)\right], \textit{ for } 0 \le S1 \le 5 \\ 1/3.4, \textit{ for } S1 > 5 \end{vmatrix} \quad \textbf{[5]}$$

For Y < 1 kT the scaling exponent is: $\alpha = \alpha_1$ **[6]**

For Y > 20 kT the exponent is: $\alpha = \alpha_{20}$ **[7]**

and for the interpolation region (1 kT ≤ Y ≤ 20 kT) do equations **[8]** and **[9]**:

For weapons with high radiative output, g = 0, and for weapons with low radiative output:
g = 1 – minimum{1, maximum[0, log(Y)/log(20)]}. **[8]**
The interpolated α scaling exponent is: $\alpha = \alpha_{20} + g\{\alpha_1 - \alpha_{20}\}$ **[9]**

The non-deeply-buried scaled crater volume, SV, for all cases except for Y > 20 and dry soil, is given by:
$SV = (L/J)\ \mathrm{antilog}_{10}[K(\exp(F(S2)+G(S2)^2)-1)+D(S2)]$,
where coefficients K, F, G, D, L, and J are tabulated below:

Region	F	G	D	K	L
Y = 1, Buried	–1.05	–0.105	0.0573	–0.5	16989
Y = 1, Air	0.258	0.01	0.1	1.9	16989
Y = 20, Buried	–2	–0.3044	0.0707	–0.9059	5663
Y = 20, Air	0.53	0.028	–1/46	1.74	5663

Material Type	Material No.	J
Dry soil*	1	4
Wet soil	2	1
Dry soft rock	3	5
Wet soft rock	4	2
Hard rock	5	8

* for $Y < 1$ kT only

The non-deeply-buried scaled crater volume for Y>20 kT and for dry soil is given by:
$SV = 354 \text{ antilog}_{10}[0.506\{\exp(2.6(S2)+0.486(S2)^2)–1\}+2(S2)/9]$, for $–3 \leq S2 \leq 0$ **[10]**
$SV = 354 \exp[\{1–\exp(–3.967(S2)^{1.139})\}\{4.283–0.0515[5–S2]^{2.068}\}]$, for $0 < S2 \leq 5$ **[11]**
The scaled crater volume for deeply-buried bursts, for all material types is give by:
$SV = \exp(P + Q(S2) + R(S2)^2) – S$, $5 < S2 \leq 40$ **[12]**,
where the coefficients P, Q, R and S are given below:

Material type	No.	P	Q	R
Dry soil	1	9.7	0.103	–0.00143
Wet soil	2	12.54	0.029	–0.00078
Dry soft rock	3	9.34	0.131	–0.00231
Wet soft rock	4	10.45	0.089	–0.00134
Hard rock	5	8.72	0.1634	–1/370

$S = 0$ for all materials but wet soil; $S = 503^2\exp[-(S2)/30]$ for wet soil. **[13]**

For all Materials and all Yields Except in Interpolation Region: $V = (SV)Y^{3\alpha}$ **[14]**

For all Materials and Yields Within the Interpolation Region:
$V = (SV_{20})[SV_1/SV_{20}]^g Y^{3\alpha}$ **[15]**
where SV_1 and SV_{20} are scaled volumes computed at 1 and 20 kT.

6.2 Apparent Crater Volume for Two or Three Material Layers: Compute a volume for each layer separately, using the full yield, the relevant cratering efficiency, and the single-layer equations above; denote these by V_{M1}, V_{M2} and V_{M3} (if needed). Then compute an average volume from these by the procedure described below:

2 Layers: $V = \hat{V}_A(V_{M1}, V_{M2}, T1)$, 3 Layers: **[16]**

$V = \hat{V}_A\left(V_{M1}, \hat{V}_A\left(V_{M2}, V_{M3}, T2\right), T1\right)$ **[17]**

$\hat{V}_A\left(V_U, V_L, T\right)$ is an approximation to $V\left(V_V, V_L, T\right)$ that satisfies the equation:

$V_A = (V_L - V_U)\exp\left(\frac{-5.4T}{V_A^{1/3}}\right) + V_U$ **[18]**, where V_A= average volume, V_U= upper layer volume, V_L=lower layer volume, and T=layer thickness. $\hat{V}_A$ is computed iteratively by the procedure:

$V_0 = \left(V_U V_L\right)^{1/2}, V_{i+1} = \left(V_L - V_U\right)\exp\left(\frac{-5.4 \cdot T}{V_i^{1/3}}\right) + V_U$ **[19–20]**

The apparent crater volume is equal to the fifth term in the series: $\hat{V}_A = V_5$ **[21]**

Radius, Depth and Ejecta Thickness: The apparent crater radius, CR, and depth, CD are given by:

$CR = 1.2V^{1/3}$ **[22]**, $CD = 0.5V^{1/3}$ **[23]**

and the minimum ground range for the debris calculation is then 1.8 times the apparent crater radius, CR. The ejecta thickness is given by the expression: $EJ = kV^{1.62}(GR)^{-3.86}$ **[24]**, where k=0.9 for dry and wet soil materials and k=1.17 for all rock materials.

7. Nuclear Weapon, Material and Radiation Types

7.1 Nuclear Weapon Types (for Section 3. Initial Radiation)

Type	Description	Yield Range (kT)
1	Gun-assembly fission weapon	0.1 to a few tens
2	Boosted or unboosted fission implosion weapon, old design	1 to a few tens
3	Unboosted fission implosion weapon, contemporary design	less than 1
4	Boosted fission implosion weapon, contemporary design	1 to a few tens
5	Boosted fission implosion weapon, modern design	1 to a few tens
6	Unboosted fission implosion	less than 1
7	Boosted fission implosion	1 to 10
8	Thermonuclear having a single yield	a few tens to 5000
9	Thermonuclear having multiple yields; high yield option	100 to 500
10	Thermonuclear having multiple yields; low yield option	a few tens
11	Tactical (clean) thermonuclear	a few tens to a few hundreds
12	Thermonuclear, very high yield	greater than 5000
13	Enhanced radiation (user familiarity with specific applications is required for meaningful results)	N/A

7.2 Material Types and Radiation Types (for Section 6. Cratering Equations)

Layers are specified by entering thicknesses for all but the bottommost layer (which is assumed to have semi-infinite thickness), and values identifying the generic types of geologic material they comprise. The structure of the calculation is such that a three-layer medium is assumed. If only a one- or two-layer calculation is desired, the geologic material type for the unwanted layers must be set to NO LAYER PRESENT.

Geologic Material Types:

*NO LAYER PRESENT	DRY SOFT ROCK
DRY SOIL	WET SOFT ROCK
WET SOIL	HARD ROCK

*Only for layers #2 and #3

Cratering efficiencies are greater for low-yield weapons than for high (greater than 20 kT). For the cratering calculations using the NORMAL RADIATION weapon radiation output, the program interpolates in the 1 to 20 kT region to provide a smooth transition. If a weapon of less than 20 kT is known to have a high radiative output, the weapon radiation output whould be set to HIGH RADIATION. This option attributes to the low yield weapon the low cratering efficiency it would have if it were of a high yield.

For Y = 1 kT, $SV = C0 + C1*S^2 + C2*S2^2 + C3*S2^3 + C4*S2^4 + C5*S2^5$, where the coefficients C0-C5 are given below for the five geologic material types:

	Dry Soil	Wet Soil	Dry Soft Rock	Wet Soft Rock	Hard Rock
C5	5e–5	6e–5	5e–5	5e–5	5e–5
C4	3e–3	3.1e–3	3.1e–3	3e–3	3.1e–3
C3	1.4e–2	1.39e–2	1.39e–2	1.39e–2	1.39e–2
C2	–5.53e–2	–5.55e–2	–5.54e–2	–5.54e–2	–5.54e–2
C1	–0.4412	–0.4408	–0.4409	–0.441	–0.441
C0	3.6233	4.2255	3.5265	3.9244	3.3224
Av. err. (%)	0.63	0.50	0.63	0.56	0.67

8. Mathematics of Vulnerability to Nuclear Weapons

Source: Mathematical Background and Programming Aids for the Physical Vulnerability System for Nuclear Weapons; Defense Intelligence Agency (written by Gilbert C. Binninger, Paul J. Castleberry, Jr. and Patsy M. McGrady under the supervision of John W. Burfening of the Physical Vulnerability (Nuclear) Branch of the Targets Division, Defense Intelligence Agency), 1 November 1974, DI-550-27-74.

The 1974 DIA document is noteworthy because it reflects the adoption of the cumulative lognormal function to describe probability of damage as a function of distance from the detonation point, rather than the circular coverage function. The cumulative lognormal function was chosen as the best fit the Hiroshima and

Nagasaki data for the collected probability of damage versus pressure. Distance damage functions are functions describing the probability of damage versus range derived by combining the pressure-damage curves discussed in this section with the pressure versus range curves described above. In addition, weapon delivery error must be included in the calculation.

The lognormal density function with variable r and parameters α and β is given by:

$$p(r;\alpha,\beta) = \frac{1}{\sqrt{2\pi}\beta \cdot r} e^{-\frac{1}{2}\left[\frac{1}{\beta}\ln\left(\frac{\alpha}{r}\right)\right]^2} \quad \textbf{[1]}$$

for r > 0 and ln is the natural logarithm. p(r;α,β) is a density function over the range (0,∞). The parameter α is the median of the lognormal density distribution function, or the distance from ground zero where there is a 50% chance of achieving the specified level of damage. In mathematical terms:

$$\int_0^{\alpha} p(r;\alpha,\beta)dr = \tfrac{1}{2} \quad \textbf{[2]}$$

The parameter β is the standard deviation of ln(r).

The cumulative lognormal function is defined as:

$$P(r) = \int_0^{r} p(r;\alpha,\beta)dr = \int_{z(r)}^{\infty} \frac{1}{\sqrt{2\pi}} e^{-y^2/2}\, dy \quad \textbf{[3]}$$

$$z(r) = \frac{1}{\beta}\ln\left(\frac{\alpha}{r}\right) \quad \textbf{[4]}$$

The distance damage function, $P_d(r)$, is the complement of P(r):

$$P_d(r) = 1 - \int_{z(r)}^{\infty} \frac{1}{\sqrt{2\pi}} e^{-y^2/2}\, dy = \int_{-\infty}^{z(r)} \frac{1}{\sqrt{2\pi}} e^{-y^2/2}\, dy \quad \textbf{[5]}$$

$P_d(r)$ is the probability that a target will receive *at least* a specified level of damage, so that $1–P_d(r)$ is not the probability of survival but the probability of receiving less than the specified level of damage.

The parameters α and β uniquely determine the distance damage function. Historically, the Defense Intelligence Agency Physical Vulnerability (DIA PV) methodology has used two other quantities to specify the distance damage function: the weapon radius (WR) and the distance damage sigma (σ_d):

$$WR = \sqrt{\langle r^2 \rangle}\,, \quad \sigma_d^2 = \frac{\langle r^2 \rangle - \langle r \rangle^2}{\langle r^2 \rangle} \quad \textbf{[6, 7]}$$

Given a uniform distribution of like targets, the WR is the radius of a circle centered at the ground zero (GZ) that contains as many targets *undamaged* to a specified level inside as there are targets *damaged* to a specified level outside. Thus if the undamaged targets inside the circle are replaced with the damaged targets outside the circle, the circle of radius WR would enclose an area entirely damaged to the specified level. The mean area of effectiveness (M.A.E.) of a weapon is defined as the area over which a weapon on the average achieves at least a specified level of damage, and is equal to πWR^2. Small values of σ_d indicate a relatively rapid fall off of the damage function, and large values of σ_d indicate a more gradual fall off. The WR and σ_d may be expressed in terms of α and β:

$$WR = \alpha \cdot e^{\beta^2}; \; \sigma_d^2 = 1 - e^{-\beta^2}; \; \beta = \sqrt{-\ln\left(1 - \sigma_d^2\right)} \text{ and } r_{50} \equiv \alpha = WR\left(1 - \sigma_d^2\right). \quad \textbf{[8–11]}$$

In some cases, two or more weapons effects may significantly contribute toward damaging a target (e.g., personnel casualties may result from blast effects and/or radiation effects). Here the WR has a larger value than it would for either effect alone. For three effects, i=1,2,3, the combined distance damage function is:

$$P_d(r) = 1 - \left(1 - P_{d1}(r)\right)\left(1 - P_{d2}(r)\right)\left(1 - P_{d3}(r)\right) \quad \textbf{[12]}$$

This methodology assumes the independence of effects.

The circular error probability (CEP) is a measure of weapon system accuracy. It is the radius of a circle centered at the desired ground zero (DGZ) within which 50% of the impact points will fall if the distribution of impact points is assumed to be normally distributed about the DGZ:

$$\frac{1}{2} = \int_0^{2\pi} \int_0^{CEP} \frac{1}{2\pi\sigma^2} e^{-r^2/2\sigma^2} r\,dr\,d\theta, \quad \textbf{[13]}$$

implying CEP = 1.1774 × σ

In general, all that is known in a problem is the distance from the aimpoint to the target. The actual distance from the weapon detonation point to the target is uncertain due to inaccuracies in the weapon delivery system, expressed through the CEP parameter. The results of an attack can not be predicted with certainty; all that can be predicted in most cases is what is most likely to happen, or what will happen on average. The PV system calculates an average probability of damage by weighting the probability of damage for each possible detonation point by the probability that the weapon lands at that detonation point:

$$P = \int_0^{2\pi} \int_0^{\infty} P_d(r) \frac{1}{2\pi\sigma^2} \exp\left[\frac{-\left(r^2 + x^2 - 2rx\cos\theta\right)}{2\sigma^2}\right] r\,dr\,d\theta \quad \textbf{[14]}$$

where $P_d(r)$ is the distance damage function, above, σ is related to the CEP as above, and x is the distance from the aimpoint (or DGZ) to the target.

Average probabilities of damage to area targets are obtained by dividing the area target into small cells which can be treated as point targets, calculating the probability of damage to each cell, weighting these probabilities by the area of the cell or the portion of the target in the cell, and averaging the results. There are two analytical methods for calculating probabilities of damage to area targets for the special cases of normally-distributed elements in an area target, and for the case where damage to some part of the area target satisfies the damage objective (e.g., breaching a dam at a point).

Some area targets, such as population centers, exhibit a concentration of target elements in the center which tends to become less as the distance from the target center increases. In this case the distribution of target elements (i.e., people) can be well described by a circular normal distribution. The P-95 is defined as the radius of the smallest circle which encompasses at least 95 percent of the population being considered:

$$0.95 = \int_0^{2\pi} \int_0^{P-95} \frac{1}{2\pi\sigma_t^2} e^{-\frac{t^2}{2\sigma_t^2}} t\,dt\,d\theta \quad \textbf{[15]}$$

which gives the target sigma, σ_t, as P–95/2.44. Since both the delivery error and target density are normally distributed, the joint density function is also normally distributed. The variance of a joint distribution of independent random variables is the sum of the variances of those random variables, or in terms of an adjusted CEP, CEP_a:

$$CEP_a = 1.1774\sigma_a = \sqrt{CEP^2 + 0.231 \cdot (P-95)^2} \quad \textbf{[16]}$$

where CEP is the delivery CEP.

For certain special classes of targets such as bridges, dams, locks, runways, etc., a specified degree of damage to some part of the target satisfies the damage objective. For example, for a bridge the collapse of one span is usually the damage objective. For the Equivalent Target Area (ETA) approximation, the ETA is defined as an area such that the probability of placing the ground zero (GZ) in the area is equal to the probability of doing the desired level of damage to the target. For a rectangular target the ETA is approximated by adding marginal strips around each edge of the target of width equal to the weapon radius for that aspect of the target. Then the probability of damage to a rectangle having a length l and width w is approximately the probability of placing a weapon in a rectangular area of length ($l+2WR_l$) and width of ($w+2WR_w$) where WR_l is the weapon radius associated with the length vulnerability number (VN, defined below) and WR_w is the weapon radius associated with the width VN. This probability may be approximated by:

$$P = 0.25 * \left[\frac{|b|}{b} erf\left(\frac{|b|}{\sqrt{2}\sigma_l}\right) - \frac{|a|}{a} erf\left(\frac{|a|}{\sqrt{2}\sigma_l}\right)\right] \times \left[\frac{|d|}{d} erf\left(\frac{|d|}{\sqrt{2}\sigma_w}\right) - \frac{|c|}{c} erf\left(\frac{|c|}{\sqrt{2}\sigma_w}\right)\right] \quad \textbf{[17]}$$

where erf is the error function, $a=x1-WR_l$, $b=x2+WR_l$, $c=y1-WR_w$, $d=y2+WR_w$; (x1,y1),(x2,y2) are the coordinates of the physical bounding rectangle for the target; σ_d is the damage sigma (with values between 0.1 and 0.5), and:

$$\sigma_w = \sqrt{CEP^2 + \left(1.774\sigma_d^2\right)^2 WR_w^2}, \quad \sigma_l = \sqrt{CEP^2 + \left(1.774\sigma_d^2\right)^2 WR_l^2}. \quad \textbf{[18–19]}$$

For the vulnerability number (VN) coding system, a target's susceptibility to blast damage is indicated by a combination of numbers and letters. The vulnerability number (VN) consists of a two-digit number reflecting the target hardness relative to a specified damage level, a letter indicating predominant sensitivity to overpressure (P) or dynamic pressure (Q), and a K factor. The two-digit numerical value scale of the VN is an arbitrary classification describing a target's hardness. It is a linear function of the logarithm of the peak pressure from a 20 kt weapon that would have a 50% probability of damaging a randomly-orientated target to the desired level. The base yield was chosen to be 20 kt instead of the more convenient 1 kt because the original system was developed from the Hiroshima-Nagasaki data assuming that the yields of the Hiroshima and Nagasaki weapons were 20 kt. The appropriate damage sigma for P targets unless otherwise specified is σ_d=0.20. The appropriate damage sigma for Q targets unless otherwise specified is σ_d=0.30. The K factor allows for hardness adjustments to be made to account for the effects of variations in blast wave duration due to different weapon yields. Each VN must also have a specified damage-level criterion, such as "collapse," "24-hour recovery time," "severe damage to contents," "moderate structural damage," etc.

The completely arbitrary coding relationship for P type targets is:

$$p_{50} = 1.1216(1.2)^{PVN}, \text{ or } PVN = 12.63 \log_{10} p_{50} - 0.63 \quad \textbf{[20–21]}$$

Since the peak overpressure at a given range is uncertain to roughly ± 20%, this coding relationship insures that P type target hardnesses are not specified more precisely than justified by the pressure-range data. This scale conveniently allows for the complete pressure range of interest to be coded by a two-digit number.

The dynamic pressure coding scale was chosen using the approximate form of the Rankine-Hugoniot equation, $q=0.023p^2$. The scale was defined so that the dynamic pressure required for a 50% probability of damage, q50, for the VN of interest is equal to $0.023p_{50}^2$ where p_{50} is from the numerically equal P VN*. Therefore, the VN's are "tied" at the 50% probability but not at the other probabilities. The relationship between the QVN and q50 is:

$$q_{50} = 0.02893(1.44)^{QVN}, \text{ or } QVN = 6.31 \cdot \log_{10} q_{50} + 9.72 \quad \textbf{[22–23]}$$

Since the dynamic pressure is only known to within about ±40%, Q type target hardnesses are also not specified more accurately than justified by the pressure range data.

* Care should be taken not to use the equation $q=0.023p^2$ to calculate the peak dynamic pressure corresponding to a given overpressure. For overpressures below about 10 psi the equation $q=0.023p^2$ is a good approximation to the Rankine-Hugoniot relation $q=(5/2)(p^2/[7p_0+p])$ where p_0 is the ambient atmospheric pressure. This Rankine-Hugoniot relation was derived assuming an ideal shock front. It only fits the available experiment data fairly well for zero heights-of-burst (HOB). The correct determination of the q given p or vice versa for a given HOB must be through the horizontal ground range using pressure-range-HOB curves.

The blast wave duration varies with weapon yield. The increased blast duration associated with larger yields may cause targets to fail at lower pressure levels, while at small yields the reduced blast duration may necessitate higher pressures for the target to fail. To account for this yield dependence, the PV system uses K-factors for both P and Q targets. The K-factor is an integer from 0 to 9 which adjusts the base VN to reflect the sensitivity of the target the different pressure-time pulse shapes for yields other than 20 KT. A K factor of 0 indicates a target that is not sensitive to blast wave duration and can be expected to fail at the same pressure regardless of weapon yield. A K factor of 9 indicates a target that is very sensitive to blast wave duration and can be expected to fail at quite different pressures at various yields.

The adjustment factor R is the ratio of the pressure (either overpressure, p(Y), or dynamic pressure, q(Y), required for a 50% probability of damage at yield Y to the pressure required at 20 KT (p(20) or q(20)). The K factor is related to the adjustment factor, R, in the following manner:

$$R = 1 - \frac{K}{10}\left(1 - \frac{t_{do}}{t_d}\right) = \frac{p(Y)}{p(Y = 20)} \; or \; \frac{q(Y)}{q(Y = 20)} \quad \textbf{[24]}$$

where t_{do} is the positive phase blast wave duration for 20 kt and t_d is the positive phase blast wave duration for yield Y ($t_d \approx 0.45(Y^{1/3}/p^{1/2})$ for overpressure, $t_d \approx 0.105(Y^{1/3}/q^{1/3})$ for dynamic pressure).

The adjustment factor R is used to determine the adjusted VN (VN_a) using the PVN and QVN coding relationships:

$$\text{for P VN's, } A = \frac{\log(R)}{\log(1.2)}, VN_a = VN + A; \quad \textbf{[25]}$$

$$\text{for Q VN's, } A = \frac{\log(R)}{\log(1.4)}, VN_a = VN + A. \quad \textbf{[26]}$$

It is often necessary to know not only p50 for a given VN and yield, but also the pressures for other probabilities of damage. The method used to obtain the pressure Pa for a probability of damage a% for the adjusted VN of v2 is discussed below.

For type P targets, the VN coding relationship gives: $p_{50}=1.1216(1.2)^{v2}$. The analysis of the Hiroshima-Nagasaki and Nevada test data resulted in the adoption of the following relationship between the overpressure required to damage a structure to a given level and the pressure which gives a 50% probability of damage, p_{50}:

$$p_a = p_{50}e^{0.297b}, \text{ where a is given by: } a = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{b} e^{-x^2/2}\,dx \quad \textbf{[27–28]}$$

and b is the probability as expressed as probits-5 (A probit has the magnitude of the standard deviation. Minus 5 probits is defineds as a=0%, 5 probits is 50%, and 10 probits corresponds to a=100%). For dynamic pressure:

$$q_{50} = 0.02893(1.44)^{v2}, \text{ and } q_a = q_{50}e^{1.042b}. \quad \textbf{[29–30]}$$

This was questioned.

ENDNOTES

Chapter One

1 George W. Bush, "Remarks to Students and Faculty at National Defense University," Fort Lesley J. McNair, Washington, DC, May 1, 2001.

Chapter Two

1 There is a modest literature that describes the evolution of the plan and some of the details. Desmond Ball and Jeffery Richelson, eds., *Strategic Nuclear Targeting* (Ithaca: Cornell University Press, 1986); Scott D. Sagan, *Moving Targets: Nuclear Strategy and National Security* (Princeton, NJ: Princeton University Press, 1989); Steven T. Ross, *American War Plans, 1945–1950* (London: Frank Cass, 1996).

2 David Alan Rosenberg, "U.S. Nuclear War Planning, 1945–1960," in Ball and Richelson, eds., *Strategic Nuclear Targeting*, pp. 35–56; Steven T. Ross, *American War Plans: 1945-1950* (London: Frank Cass, 1996).

3 Rosenberg, in Ball and Richelson, p. 54.

4 Desmond Ball, "The Development of the SIOP, 1960–1983," in Ball and Richelson, pp. 57–83; Aaron L. Friedberg, "A History of the U.S. Strategic `Doctrine, 1945 to 1980," *Journal of Strategic Studies*, Vol. 3, No. 3 (December 1980), pp. 37–71.

5 Quoted in Ball, p. 64.

6 Quoted in Ball, p. 67.

7 Jeffrey Richelson, "PD-59, NSDD-13 and the Reagan Strategic Modernization Program," *The Journal of Strategic Studies*, Vol. 6, No. 2 (June 1983), pp. 125–146.

8 Richard Halloran, "Pentagon Draws Up First Strategy For Fighting a Long Nuclear War," *New York Times*, May 30, 1982, p.1.

9 Department of Defense, News Briefing, October 29, 1993.

10 DOD Transcript, No. 546-94, September 22, 1994. Senate Armed Services Committee, *Briefing on Results of the Nuclear Posture Review*, S. Hrg. 103-870, September 22, 1994.

11 Janne E. Nolan, *An Elusive Consensus: Nuclear Weapons and American Security After the Cold War* (Washington, DC: Brookings, 1999).

12 R. Jeffrey Smith, "The Dissenter," *The Washington Post*, December 7, 1997, p. W18.

13 U.S. Congress, Senate Appropriation Defense Subcommittee, FY 1991 Defense Appropriations Hearing, June 12, 1990.

14 Ron Rosenbaum, "The Subterranean World of the Bomb," *Harper's* (March 1978), p. 96.

15 VADM Gerald E. Miller (USN ret.), "Beres and Others Have No Access to the 'True Strategy,'" *Center Magazine*, November/December 1982.

16 Bruce G. Blair, "Trapped in the Nuclear Math," The *New York Times*, June 12, 2000, p. A29.

17 R. Jeffrey Smith, "Clinton Directive Changes Strategy on Nuclear Arms," *The Washington Post*, December 7, 1997, pp. A1 and A8.

18 *Ibid.*

19 *Ibid.*

20 Recent SIOPs (and date of implementation) are:
SIOP-5, January 1, 1976
SIOP-6, October 1, 1983
SIOP-6F, January 1, 1989
SIOP-6G, October 1, 1990
SIOP-6H, October 1, 1991
SIOP-92, October 1, 1991
SIOP-93, June 1, 1992
SIOP-94, October 1, 1993
SIOP-95, October 1, 1994
SIOP-96, October 1, 1995
SIOP-97, October 1, 1996
SIOP-98, October 1, 1997
SIOP-99, October 1, 1998
And, presumably,
SIOP-01, October 1, 2000

21 Jeff Greenfield and George Crile, "Rehearsing Doomsday," CNN Democracy in America, Transcript # 00101500V66, October 15, 2000.

22 "Group Urges U.S. To Reduce Nuclear Warheads," Armed Forces Newswire Service, May 19, 2000.

23 Kenneth McGill, "USSTRATCOM/J53 War Plan Analysis," MSRR/MEL Users Conference, April 1999.

24 *Ibid.*

25 Bruce G. Blair, "Too Many Missiles, Too Many Targets," *Sacramento Bee*, June 25, 2000, p. I1.

26 During the last two decades of the Cold War, Pentagon spokesmen frequently employed this phrasing as a kind coded reference to the alleged need to target and severely damage Soviet nuclear forces and underground command centers, on the grounds that the heirs of Stalin could not be relied upon to value their own population and industry sufficiently to refrain from escalation to nuclear warfare, especially in the event that NATO forces fired first.

27 Eric Schmitt, "Pentagon Feels Pressure to Cut Out More Warheads," *The New York Times*, May 11, 2000, p. 1.

28 George W. Bush, "Remarks to Students and Faculty at National Defense University," Fort Lesley J. McNair, Washington, DC, May 1, 2001.

Chapter Three

1 Three nuclear warhead types were designed at Lawrence Livermore National Laboratory (W62, B83, and W87) and the remaining six types at Los Alamos National Laboratory (W78, W76, W88, B61-7, B61-11, and W80-0).

2 Bruce G. Blair, "Trapped in the Nuclear Math," *The New York Times*, June 12, 2000, p. A29.

3 DOD, Joint Staff, "Reporting Manual for Joint Resources Assessment Database System (JRADS)," CJCSM 3150.09, 15 March 1999), pp. 2 and A-1.

4 *Ibid.*

5 See "functional classification code" in William M. Arkin and Hans Kristensen, "The Post Cold War SIOP and Nuclear Warfare Planning: A Glossary, Abbreviations, and Acronyms," Natural Resources Defense Council, January 1999.

6 For the National Imagery and Mapping Agency's publicly available database, see: http://164.213.2.59/gns/html/index.html.

7 1° (longitude at the equator) = 1,855 meters; 1° (latitude at the equator) = 1,862 meters; and 1° (latitude at the pole) = 1,843 meters.

8 www.fos.org.

9 Kevin C. Ruffner, ed., CORONA: *America's First Satellite Program* (Washington, D.C.: Center for Study of Intelligence, Central Intelligence Agency, 1995).

10 Oleg Bukharin, Thomas B. Cochran, and Robert S. Norris, "New Perspectives on Russia's Ten Secret Cities," (Washington, D.C.: Natural Resources Defense Council, October 1999).

11 Ruffner, *CORONA,* pp. xiv–xv.

12 *Ibid.*

13 *Ibid.*

14 *Ibid.*

15 See, for example, Thomas B. Cochran, Robert S. Norris, and Oleg A. Bukharin, *Making the Russian Bomb: From Stalin to Yeltsin* (Boulder: Westview Press, 1995).

16 Oleg Bukharin, Thomas B. Cochran and Robert S. Norris, "New Perspectives on Russia's Ten Secret Cities," (Washington, D.C.: Natural Resources Defense Council, October 1999).

17 See, for example, Thomas Nilsen, Igor Kudrik, and Alexandr Nikitin, *The Russian Northern Fleet,* (Norway: Bellona Report Volume 2, 1996).

18 Mr. Handler was the Greenpeace disarmament campaign coordinator and is currently a graduate student at Princeton University. See his, "The Northern Fleet's Nuclear Submarine Bases," *Jane's Intelligence Review,* December 1993—Europe, pp. 551–556; and "Russia's Pacific Fleet—Submarine Bases and Facilities," *Jane's Intelligence Review,* April—Europe, pp. 166–171.

19 Samuel Glasstone and Philip J. Dolan, eds., *The Effects of Nuclear Weapons,* Third Edition, United States Department of Defense and Department of Energy, 1977.

20 Philip J. Dolan, editor, *Capabilities of Nuclear Weapons: Defense Nuclear Agency Effects Manual Number 1,* Headquarters, Defense Nuclear Agency, Washington, D.C., 20305. Obtained through the Freedom of Information Act, February 13, 1989.

21 Computer code "Blast Effects," developed by Horizons Technology, Inc. (7830 Clairemont Mesa Blvd., San Diego, CA 92111) for the Director, Defense Nuclear Agency, Washington DC 20305, Version 2.1, December 21, 1984.

22 Computer code "Weapon Effects," developed by Horizons Technology, Inc. (7830 Clairemont Mesa Blvd., San Diego, CA 92111) for the Director, Defense Nuclear Agency, Washington DC 20305, Version 2.1, December 21, 1984.

23 Harvey, T. F., private communication of KDFOC3 FORTRAN IV source code and 34 pages (entitled 3. USERS MANUAL: INPUT AND ALGORITHMS) of a LLNL report regarding KDFOC3. For another study discussing KDFOC3 see Per Ljung and Kenneth Nyren, "Nuclear Fallout Simulations Using KDFOC3," National Defense Research Establishment (FOA), Department of NBC Defense, Sweden, May 1984 (available from the U.S. Department of Commerce National Technical Information Service)

24 Defense Nuclear Agency, *Capabilities of Nuclear Weapons,* DNA EM-1, Part I (July 1, 1972), p. 5-1. Additional nuclear radiation arises from the neutron activation of the earth below an air burst and fallout, which are discussed later in this chapter.

25 Another example where the weapon effect of initial radiation depends on the type of nuclear weapon would be a phenomenon termed "hydrodynamic enhancement." Gamma rays produced by fission products emanate from the rising nuclear fireball, and the reduction in air density behind the blast wave allows these gamma rays to travel more efficiently from the fireball to persons in the vicinity of the explosion. This effect is called hydrodynamic enhancement. For "Fat Man" and "Little Boy" the prompt neutrons accounted for most of the harmful dose to Japanese victims of the bombing. But for thermonuclear weapons in the megaton yield range, hydrodynamic enhancement makes the fission product gamma rays a more significant source of initial radiation than the prompt neutrons. DNA EM-1, pp. 5–23.

26 "In the report (Hiroshimashi-Nagasakishi, p. 31) sent to the Secretary-General of the United Nations by both cities in the autumn of 1976, the total deaths following exposure to the bomb by the end of 1945 totaled 140,000 (+/– 10,000) in Hiroshima and 70,000 (+/- 10,000) in Nagasaki." From *Hiroshima and Nagasaki: The Physical, Medical, and Social Effects of the Atomic Bombings,* (New York: Basic Books, 1981) p. 113.

27 John Malik, "The Yields of the Hiroshima and Nagasaki Nuclear Explosions," LA-8819, Los Alamos National Laboratory, September, 1985.

28 "The Epicenter of the Atomic Bombs. 2. Re-evaluation of All Available Physical Data with Recommended Values," in the Atomic Bomb Casualty Commission Technical Report, 1969.

29 Hiroshima Shiyakusho [Hiroshima City Office], *Hiroshima Genbaku Sensaishi* [Record of the Hiroshima A-bomb War Disaster], Hiroshima, 1971, vol. I.

30 Theodore A. Postol, "Possible Fatalities from Superfires Following Nuclear Attacks in or near Urban Areas," reprinted by the International Strategic Institute at Stanford University, Center for International Security and Arms Control from *The Medical Implications of Nuclear War,* (Washington, D.C.: National Academy of Sciences Press, 1986).

31 Arthur M. Katz, *Life After Nuclear War: The Economic and Social Impacts of Nuclear Attacks on the United States* (Cambridge, MA: Ballinger Publishing Company, 1982).

32 T. Harvey, *et al.,* "Internal Dose Following a Large-Scale Nuclear War," LLNL, 1986.

33 DELFIC was developed by the U.S. Defense Nuclear Agency with the "aim to give warranted attention to all phenomena that were considered significant." Reportedly it is the most sophisticated model: it was developed for research purposes and other models use it for calibration. In calculating fallout, it is necessary to convert the quantity of gross fission products produced to a dose rate. The dose rate is calculated one meter above a smooth plane one hour after the detonation and with one kt per km^2 of gross fission products uniformly distributed. KDFOC3 uses a conversion factor of 70 $(Sv/hr)(km^2/kt)$. DELFIC uses a gross fission conversion factor of K = 54 $(Sv/hr)(km^2/kt)$. Reference: "Nuclear Fallout Simulation Using KDFOC3," p. 21.

34 SEER3 was developed in the early 1970s by Stanford Research Institute as a simplified version of DELFIC (assumes a stabilized cloud without a stem, uses few discs, and incorporates some curve-fitting to DELFIC).

35 WSEG10 was first developed by the U.S. Defense Department in 1959. The 1981 improved model [Bridgman, C.J. and Bigelow, W.S., "A New Fallout Prediction Model," *Health Physics,* 43 (1982): 2, 205–218.] uses a gross fission conversion factor of K = 47 $(Sv/hr)(km^2/kt)$.

36 Pertaining to fallout, nuclear weapons have been generally classified into five types depending on the amount of residual radiation produced in the explosion. From least to greatest residual radiation produced in the explosion the types are: minimum residual radioactivity weapon, clean weapon, normal weapon, dirty weapon and salted weapon. A minimum residual radioactive weapon is "designed to have optimum reduction of unwanted effects from fallout, rainout, and burst-site radioactivity." A clean weapon is a "nuclear weapon in which measures have been taken to reduce the amount of residual radioactivity relative to a 'normal' weapon of the same energy yield." A dirty weapon "produces a larger amount of radioactive residues than a 'normal' weapon of the same yield. It is a fission weapon or any other weapon that would distribute relatively large amounts of radioactivity upon explosion, as distinguished from a fusion weapon." A salted weapon "has, in addition to its normal components, certain elements or isotopes that capture neutrons at the time of the explosion and produce radioactive products over and above the usual radioactive debris." KDFOC3 calculates a fission-equivalent yield for the fusion part of the total yield, using a 10 percent fission-equivalent yield for an air burst and 18 percent for buried bursts. These definitions are from Kenneth E. Gould and Kaman Tempo, *Glossary of Terms—Nuclear Weapon Phenomena and Effects*, Prepared for the Director, Defense Nuclear Agency, Washington, DC (Contract No. DNA 001-82-C-0274), February 15, 1985, pp. 163–165.

37 "Nuclear Fallout Simulation Using KDFOC3," p. 25.

38 *Ibid.*

39 General Electric Company—TEMPO. Compilation of Local Fallout Data from Test Detonations 1945–1962. Vol. 1: "Continental US Tests." Vol. 2: "Oceanic U.S. Tests." Washington, D.C.: Defense Nuclear Agency, DNA 1251-1 and -2, 1 May 1979.

40 The dose-rate contours given in these volumes are given at H+1 hour, a convention used to facilitate comparison of data with calculations: "The dose-rate contours for the fallout patterns have been drawn to show the gamma dose rate in roentgens per hour, three feet above the ground, in terms of the one hour after burst reference time. The $t^{-1.2}$ approximation was used when no actual decay data were available to adjust radiation measurements to the one-hour reference time. It is important to recognize the H+1 hour is used as a reference time, and that only the contours from low yield weapons are complete at one hour after burst. For high-yield weapons, fallout over some parts of the vast areas shown does not commence until many hours after the burst." General Electric Company—Tempo, pp. 2-3.

41 General Electric Company—Tempo, p. 63.

42 NATO *Target Data Inventory Handbook* (NTDI) (U), Headquarters United States European Command and Defense Intelligence Agency ("produced by the HQ USEUCOM Intelligence Targets Division for the Defense Intelligence Agency"), January 1, 1989 (released under the Freedom of Information Act, with deletions, 1998) and Physical Vulnerability Handbook-Nuclear Weapons (U), Defense Intelligence Agency, AP-550-1-2-69-INT (unclassified), January 28, 1974, and "Mathematical Background and Programming Aids for the Physical Vulnerability System for Nuclear Weapons," Defense Intelligence Agency (prepared for the Defense Intelligence Agency, Directorate for Intelligence), DI-550-27-74, November 1, 1974 (unclassified).

43 "Global Gridded Upper Air Statistics: 1980-1995," Version 1.1, March 1996, National Climactic Data Center (a part of the National Oceanic and Atmospheric Administration), Asheville, North Carolina.

44 The University of Washington Geospatial Data Archive contains GIS boundary data for most of the Russian *rayons* and *gorsovets* as part of their "Russian Federation Digital Data" archive (http://wagda.lib. washington.edu/data/russianfed/).

45 Furthermore, the population within a P-95 circle is assumed to have a log-normal distribution within that circle. In a log-normal distribution, the logarithm of the population has a normal, or Gaussian, distribution peaking at the center and falling off towards the circumference. There are U.S. Department of Defense algorithms (which NRDC possesses) for readily calculating casualties from a nuclear burst based on the log-normal distribution in a P-95 circle.

46 "The Feasibility of Population Targeting," pp. 32–33.

47 Kenneth McGill, "USSTRATCOM/J53 War Plan Analysis," MSRR/MEL Users Conference, April 1999.

Chapter Four

1 "Of the Soviet inventory of 1,400 operational ballistic missile silos, 818 have been rebuilt since 1972. Fully one-half of these silos have been totally reconstructed and hardened since 1980." *Soviet Military Power: An Assessment of the Threat 1988*, U.S. Department of Defense, p. 46.

2 The "P" and "L" vulnerability numbers quantify the damage probability in terms of the nuclear explosive effect of peak blast overpressure. L-type numbers have a standard deviation half as large as P-type numbers. This means that the probability of achieving severe damage to a silo decreases more rapidly with the separation between ground zero and silo for L-type silos than for P-type silos.

3 "The VN for severe damage to the installation predicts one of the following: (a) collapse or severe distortion of silo door resulting in severe damage to in-silo missile or critical launch support equipment by debris impact or vented overpressure; (b) collapse or severe distortion of roof or walls of launcher equipment room (silo headworks) resulting in severe damage to critical launch support equipment by debris impact or physical dislocation; or (c) severe damage to in-silo missile by a nuclear effect." NATO Target Data Inventory Handbook, p. 681.

4 "The VN for moderate damage to the installation predicts one of the following: (a) sufficient deformation of launch silo door to prevent missile launch until door is removed by use of emergency equipment; (b) moderate structural damage to roof of launcher equipment room (silo headworks) which causes sufficient damage to launch support equipment to prevent missile launch until damaged equipment is inspected, tested, or repaired; or (c) sufficient damage by any nuclear effect to in-silo missile airframe, propulsion, or guidance system or to launch support equipment to prevent missile launch until damaged equipment is inspected, tested, calibrated or repaired." NATO Target Data Inventory Handbook, p. 680.

5 Edgar Ulsamer, "The Prospect for Superhard Silos," *Air Force Magazine*, January 1984, pp. 74–77.

6 *Ibid*.

7 "For airburst weapons, the vertical error distribution is expressed in terms of PEH. A distance of 1 PEH from the desired HOB will contain 25 percent of the detonations. A 1 PEH bracket is the vertical distance both above and below the desired HOB within which a single weapon has a 50 percent probability of detonating. The vertical distribution pattern is assumed to be normal about the desired HOB." *Nuclear Weapons Employment Effects Data* December 20, 1995, (Joint Pub 3-12.2, December 20, 1995) p. III-3. Released under FOIA October 4, 2000.

8 Seasonal variations in the ambient winds were modeled by performing fallout calculations using the most probable wind vectors at each silo location for each month of the year.

9 Because the angular resolution of the monthly wind rose data was 45 degrees, calculations for each month were performed at the most probable wind vector angles and for wind vector angles globally offset by ±15 degrees.

10 Each of the fallout calculations were performed using an ideal-plane conversion factor of 0.7 to account for the radiation shielding provided by the roughness of a real planar surface (i.e., an open field), and calculations using sheltering factors of 1 (no sheltering), 4 (sheltering typical of single-story residential structures), 7 (sheltering typical of multi-story buildings) and 40 (sheltering typical of basement environments) were performed for each wind field.

11 Calculations for each of the wind fields and for each of the sheltering factors were performed for fission fractions of 50 percent and 80 percent in order to understand the dependence of fallout casualties over the likely range of fission fractions for U.S. nuclear weapons. Fission fractions of U.S. nuclear weapons are classified. Our range of values for the W88 and W87 warheads is suggested by the known fission fractions of the tests from Operation Castle: Bravo (fission fraction = 66.67 percent); Romeo (fission fraction = 63.6 percent); Union (fission fraction = 72.5 percent); Yankee (fission fraction = 51.9 percent) and Nectar (fission fraction = 79.9 percent). The Castle tests were of early design, multi-megaton weapons. Robert S. Norris and Thomas B. Cochran, United States Nuclear Tests: July 1945 to 31 December 1992. NRDC Working Paper, February 1997, pp. 29–31.

12 *Russia's Arms and Technologies: The XXI Century Encyclopedia, Vol. 1, Strategic Nuclear Forces* (Moscow, 2000).

13 *Soviet Military Power: An Assessment of the Threat*, U.S. DOD, 1998. p. 47.

14 *Russia's Arms and Technologies*, p. 100.

15 Steven Zaloga, "Strategic Forces of the SNG," *Jane's Intelligence Review*, February 1, 1992, p. 79.

16 "Military Denies Possible Reinforcement with Russian Tactical Missiles," BBC Summary of World Broadcasts, November 17, 1998 (source: Belapan News Agency, Minsk).

17 On March 10, 1994, a Russian soldier killed his commander and two fellow soldiers with a submachine gun at the Barnaul base. Guards reportedly did not return fire immediately because they were prohibited from shooting in the direction of an SS-25, even in the event of a terrorist attack. "Silo Shooting a Cause for Concern," *Jane's Defense Weekly*, April 9, 1994, p. 15.

18 Coordinates from the START I MOU are given to the nearest minute, an uncertainty of about 900 meters in the north-south direction and at this latitude an uncertainty of about 500 meters in the east-west direction. We assume the garrison and base locations are indicated by the nearby small circles on the JOG, which indicate populated places on the map.

19 It is possible that in the intervening years the hardness of the transporter-erector-launcher (TEL) vehicles was improved. The 1989 *NATO Target Data Inventory Handbook* assigns a VN number for severe damage to wheeled vehicles, armored cars and tanks of 18Q9, 20Q9 and 24Q9, respectively.

20 "If the weapon yield is greater than several hundred tons . . . the predominant type of damage to targets in the open results from the drag force caused by dynamic pressures. These drag forces may be large enough to move properly oriented, unshielded targets great distances. They may slide, roll, or bounce along the ground surface and may be damaged seriously by the violent motions. There have been instances in which heavy equipment has been picked up and thrown dozens of feet, and then has hit the ground with sufficient force to be dismembered." From Philip Dolan, editor, *Capabilities of Nuclear Weapons: Defense Nuclear Agency Effects Manual Number 1*. Headquarters, Defense Nuclear Agency, Washington, D.C. 20305. p. 14-1.

21 *CIA's Analysis of the Soviet Union: 1947–1991*, documents released at the conference sponsored by the Center of International Studies at Princeton University and CIA's Center for the Study of Intelligence, 2001.

22 In the NATO *Target Data Inventory Handbook* (NTDI), one target category "includes all surface-to-surface missile sites," including "a facility from which a launch of mobile missile(s) could be effected." NTDI Handbook, p. 670. Within this target category a code number is assigned to the SS-25 missile. Unfortunately there is no undeleted mention of specific structure types associated with the SS-25 in the NTDI Handbook, but "Additional Data" provided for these targets in the NTDI Handbook does include the "Center of the smallest rectangle that will enclose: . . . All single-bay sliding roof garages." NTDI Handbook, p. 682.

23 In the NTDI Handbook, under the heading "Component Damage—Missile-ready

Structure," descriptions of severe and moderate damage are given along with vulnerability numbers for severe and moderate damage to two structure types which will serve as bounding values in this analysis: "The VN for severe damage to the missile-ready structure predicts failure of one or more structural elements (roof, wall, or closure) enclosing protected spaces which house missiles, equipment, and/or personnel and causing damage to contents by crushing, translation impact due to overpressure, or impact by collapse of a structural element and associated damage generally as follows: physical damage to associated equipment located at the launch site to such extent that the items are rendered inoperative and require major repair. The VN for moderate damage to the missile-ready structure predicts structural damage to the building sufficient to cause roof spall, jamming of closure(s), or movement or collision of contents such that medical treatment of personnel and/or inspection, checkout, and minor repairs of missile equipment are required and associated damage generally as follows: damage to associated equipment and facilities located at the launch site to such extent that performance is degraded, curtailed, or interrupted. NTDI Handbook, p. 679.

24 In addition, the K factor for this vulnerability number (the fourth character) is 7, meaning that these structures are very sensitive to the duration of the positive phase of the blast wave.

25 For example, a peak blast overpressure of 111 psi is calculated to produce a 50 percent probability of severe damage for a vulnerability number of 26P3, given an attacking warhead yield of 100 kt.

26 The threshold height of burst for production of local fallout from a 100 kt warhead is calculated to be 350 meters.

27 While we do not know how hardened the communications structures are at the bases, two 100 kt ground bursts should be illustrative of the risk to Russian civilians in the vicinity of these military sites.

28 As for the ICBM silo dicussion above, we performed calculations for 12 months, 3 wind conditions—the center of most probable sector direction and ± 15 degrees off center, two warhead fission fractions—0.5 and 0.8 and four sheltering factors—1, 4, 7 and 40.

29 *Soviet Military Power: An Assessment of the Threat* (1988), p. 11.

30 *Russia's Arms and Technologies,* pp. 103–04.

31 Coordinates from the START I MOU are given to the nearest minute, an uncertainty of about 900 meters in the north-south direction and at this latitude an uncertainty of about 500 meters in the east-west direction.

32 Vladimir Kuroedov, Commander-in-Chief of the Russian Navy, "Interests in the World's Oceans," *Krasnaya Zvezda,* May 24, 2000, pp. 1–2.

33 The Montreux Convention of 1936 restricts submarine passage between the Black Sea and the Mediterranean.

34 *Soviet Military Power: Prospects for Change 1989,* U.S. Department of Defense, p. 113.

35 *Russia's Arms and Technologies,* p. 178.

36 "So-called secure military zones began to be created in the Barents, White, Kara, Norwegian, Okhotsk, and Japanese seas and in ice-covered regions of the Arctic in the beginning of the 1970s. The zones were protected by minefields and were patrolled by multipurpose nuclear-powered submarines, and also by combatant surface ships and aircraft whenever possible. Safe and reliable communications with strategic missile-armed submarines were also possible in the secure zones." *Ibid.,* p. 178. Soviet (and American) SSBNs patrolled under the Arctic ice as well.

37 *Soviet Military Power 1987,* U.S. DOD, Washington, D.C., pp. 128–129. During the Cold War, the U.S. Navy had a major geographic advantage: "The Soviets could not easily reach open sea. Geography had shaped the Russian empire since before Peter the Great, and it was to stymie it again. Whether in the Arctic, the Far East or by the Black Sea to the Bosporus, the Soviets could not enter deep water without passing through choke points which made it far easier to spot and track their submarines. One choke point is the channel formed by Greenland, Iceland and the United Kingdom. It was here that the United States and allies such as Great Britain and Norway first concentrated their underwater listening devices, air surveillance and submarines. But the United States also planted listening devices near the northern tip of Japan, in the Mediterranean and at dozens of other locations. . . . The plan was to have an attack sub pick up the Soviet nuclear-missile subs and follow them on their patrols in the Atlantic and Pacific. . . . For the sub crews on this anti-submarine warfare team, the aim was to learn the Soviet boats' operational patterns and be able to identify the U.S. cities and military installations within range of the 16 missiles each carried. But the U.S. sub crews also wanted to keep the Soviet boats in their torpedo sights in case war broke out, hoping to destroy them before they could launch. "Soviets Improve Subs, Tactics," Christopher Drew; Michael L. Millenson, *Chicago Tribune;* Robert Becker: *Newport News Daily Press, The Orange County Register,* February 24, 1991, p. A29.

38 John Downing, "Navy's Needs: Hard to Justify," *Jane's Defense Weekly,* August 2, 2000, Vol. 34; No. 5.

39 "Russian Servicemen Steal Radioactive Submarine Fuel," Associated Press, February 1, 2000.

40 "Damage to Russian Naval Vessel Worse than First Admitted," ITAR-TASS News Agency, Moscow, April 11, 2000.

41 "5 Metal Collectors Die of Suffocation in Sub," ITAR-TASS News Agency, March 21, 2000.

42 Patrick E. Tyler, "Thieves Looting Russia of Its Power Lines," *New York Times,* April 18, 2000, p. A1.

43 "Admiral Sentenced to Eight Years in Prison for Embezzlement," NTV International, Moscow, April 28, 2000.

44 "Toxic Fuel Leak Reported in Russian Far East," United Press International, June 16, 2000.

45 "Russian Authorities Warn of Toxic Fuel Leaking from Tanks," AP Worldstream, July 25, 2000.

46 "Unpaid Utility's Power Cuts Put Control of Russian Pacific Fleet at Risk," Agence France Presse, July 26, 2000.

47 "Russia Solves Mystery of Huge Floating Object," *The Commercial Appeal* (Memphis, TN), August 8, 2000, p. A8.

48 "Entire Russian Navy Crew Abandon Ship, Complain of Beatings," *Segodnya,* Moscow, July 19, 2000.

49 "Russian Pacific Fleet Cancels Navy Day Parade Due to Lack of Fuel," NTV, Moscow, July 30, 2000.

50 "Russian Ship Accidentally Fires Sea-to-Shore Missile," Agence France Presse, September 15, 2000.

51 "Russian Pacific Fleet Nuclear Submarine Unit Disbanded on Cost Grounds," *Segodnya,* Moscow, October 13, 2000.

52 The Northern Fleet operates out of Russia's only year-round ice-free ports—in winter the waters of Russia's Arctic coast are icebound except for a 100-kilometer segment of the Kola Peninsula.

53 One aimpoint is centered on the piers across the Kola Inlet from Polyarnyy Naval Base.

54 "Russia Downsizes Strategic Aviation, Closes Air Bases," *Aerospace Daily,* April 16, 1998, p. 92.

55 Nuclear weapons that had been in storage at Mozdok air base at the start of the 1994 war in Chechnya were reportedly moved deeper inside Russia.

56 Nikolai Novichkov, "Russia's Air Force in Crisis Situation," *Jane's Defense Weekly*, October 11, 2000. In addition, Morozov claimed that 54 percent of frontal aviation and 62 percent of the transport fleet were serviceable.

57 The NATO Target Data Inventory Handbook (p. 540) defined one category of targets as:

"Permanent airfields which are or can be used as bomber or fighter bases. Also includes reserve airfields, seaplane stations, heliports, highway airstrips, and new installations under construction which can positively be identified as supporting aircraft operations and when potential development equals the minimum NTDI criteria."

The minimum NTDI criteria have been deleted from the declassified document, but under "Selection Criteria," it is noted, "Military aircraft in less than squadron strength are not considered for basic categorization." (p. 545) The NTDI Handbook notes that the objective for attack will vary according to the strategic or tactical situation, but offers the following list of objectives: runways; administration buildings, barracks, shops or storage buildings; hangars; aircraft in the open; aircraft in bunkers (including underground bunkers); POL storage; and conventional ammunition storage

58 "NRDC Nuclear Notebook: Russian Nuclear Forces, 2000," Robert S. Norris and William M. Arkin, *Bulletin of the Atomic Scientists*, July/August 2000, pp. 70–71.

59 See also, Joshua Handler, "Lifting the Lid on Russia's Nuclear Weapon Storage," *Jane's Intelligence Review,* August 1, 1999.

60 Anatoly Yurkin, "Safety of Nuke Arms Handling Enhanced," TASS, December 29, 2000.

61 "USA Installing Automated Nuclear Weapons Monitoring System in Russia," ITAR-TASS News Agency, Moscow, December 5, 2000 (BBC Summary of World Broadcasts, December 7, 2000).

62 General Accounting Office, "Security of Russia's Nuclear Material Improving; Further Enhancements Needed," GAO-01-312, February 2001, p. 32.

63 The United States FY 2002 budget indicates some of the Navy sites are for temporary storage, e.g. storage near the piers where the SSBNs are docked (DEFENSE NUCLEAR NONPROLIFERATION, pg. 51).

64 The Nizhniy Tagil Sites 1 and 2 and the Yuryuzan Sites are near warhead or warhead component assembly and disassembly plants, but it is our understanding that it is appropriate to characterize them as National Level nuclear warhead storage sites.

65 "Nuclear Decay—Specialists Claim It Would Take Only 26 Men to Commandeer a Nuclear Warhead," Kirill Belyaninov, Noviye Izvestia staff. *Noviye Izvestia,* February 19, 2000, pp. 1–4 (Current Digest of the Post-Soviet Press, March 22, 2000, Vol. 52, No. 8; Pg. 6). This article goes on to discuss the closing of the national-level facility at Tula and U.S. General Habiger's inspection of the Krasnoarmeyskoye national-level storage site in 1998: "State-of-the-art 'Potemkin villages' were built specifically for the official delegations, where a single facility would be equipped to perfection. . . . The first installation used as a showpiece was near Tula, but it became the site of a 'revolt of officers' wives' in 1996: These women had had it with salary arrears and blocked the access road to the installation. After that the installation was taken off line, the nuclear weapons were removed, and the officers were transferred to other units. . . . Meanwhile, all the state-of-the-art sensors and security systems were reinstalled at another showpiece facility, this one in the Volga region. It was inspected in the summer of 1998 by Gen. Eugene Habiger, commander in chief of the U.S. Strategic Command."

66 NTDI, p. 369. In the *NATO Target Data Inventory Handbook*, the storage sites are identified according to the "type of command(s) supported by the overall storage site: Air Forces, Rocket Forces, Ground Forces, Naval Forces, Air Defense Forces, Strategic Bombs, Tactical Bombs, ASM (i.e., Air-to-Surface Missile) Warheads, AAM (i.e., Air-to-Air Missile) Warheads, ICBM Warheads, IRBM Warheads, MRBM Warheads, Artillery Projectiles, Atomic Demolition Munitions (ADM), SLBM Warheads, Torpedoes/Mines, SAM (i.e., Surface-to-Air Missile) Warheads, Tactical Missile Warheads and Unknown." NTDI, p. 371.

67 Ruffner, Kevin C., ed., *Corona: America's First Satellite Program*, CIA Cold War Records, (Washington, DC: History Staff, Center for the Study of Intelligence, Central Intelligence Agency, 1995), pp. 169–173.

68 Thomas B. Cochran, Robert S. Norris, Oleg A. Bukharin, *Making the Russian Bomb: From Stalin to Yeltsin* (Boulder, CO: Westview Press, 1995).

69 Oleg Bukharin, Thomas B. Cochran, Robert S. Norris, *New Perspectives on Russia's Ten Secret Cities* (Wahington, DC: NRDC, October 1999); Oleg Bukharin, et al., *Helping Russia Downsize its Nuclear Complex: A Focus on the Closed Nuclear Cities* (Princeton University: Center of International Studies and Center for Energy and Environmental Studies, June 2000).

70 *Ibid.*

71 *Ibid.*

72 Viewgraphs presented by Lev Ryabev, First Deputy Minister of Atomic Energy, Russian Federation, "The Role of the NCI in Meeting Russia's Nuclear Complex Challenges," Washington, DC. January 11, 1999.

73 *Ibid.*

74 Lev Ryabev, First Deputy Minister of Atomic Energy, Russian Federation, "The Role of the NCI in Meeting Russia's Nuclear Complex Challenges," January 11, 1999, Washington, DC.

75 But some records are present for historical reasons and would clearly not be targeted under MAO-NF, for example the Skrunda large phased-array early warning radar, which ceased operations on August 31, 1998.

76 Russia had 61 operational communications spacecraft in 1997 "Russian Space Activity," *Air Force Magazine,* August, 1998, p. 33.

In operation since 1985, the low-orbiting *Strela-3* military communications satellites (twenty currently operational) use near polar circular orbits, and are launched in sextets into two mutually perpendicular orbital planes which provide worldwide communications relays. Strela-3 provides military store-dump (frame relay communications) for the Main Intelligence Directorate (GRU) of the General Staff of the Defense Ministry. They are referred to as "space mailboxes for Russian spies" ("Commission to Investigate Why Military Satellites Ended up in Wrong Orbit," *BBC Summary of World Broadcasts,* June 23, 1998; "Russia Orbits Six Military Communications Satellites," *Aerospace Daily,* June 18, 1998, p. 446.). The same technology was used for the civil version of the system, called Gonets-D1 (6). In 1996 and 1997 Strela-3 and Gonets-D1 satellites shared two launches to combine initial deployment of the civil system with maintenance of the military version. Problems with the 1997 launch, however, placed these six satellites into probably useless orbits.

The Raduga (7) (*Raduga* means rainbow in Russian) satellites comprise the main Russian secure military/government telecommunications system. Russia states it plans to replace the original Raduga satellites with a more capable Raduga-1 series, of which one is currently operational (Phillip Clark, "Russia's Satellite Launches on the Wane," *Jane's Intelligence Review,* November 1, 1996, p. 485). The control station for the Raduga satellites is the Main Center for the Testing and Control of Spacecraft, which is just outside Moscow in the city of Golitsino (55° 37′ N 036° 59′E).

Additional secure government/military communications for the Russian Federation is provided by the Molniya satellite system (*Molniya* means "flash of lightning" in Russian). Molniya-1 (4) are used for government and military communications whereas Molniya-3 (4) are used for TV programs. Orignially, Molniya-1 and Molniya-3 satellites operated with one satellite of each type within each of eight orbital planes, allowing 24-hour communications coverage (a total of 16 satellites). The last space launch for the Molniya-2 program was in 1977.

The Potok network (2), used for military-data relay, employs Cosmos satellites based upon a satellite bus called Geizer. There have been three Potok locations registered at 80 East, 168 West, and 13.5 West, although only the first and third locations have actually been used as of 1996. Recent Potok launches include Cosmos 2172 (November 22, 1991), Cosmos 2291 (September 21, 1994), and Cosmos 2319 (August 31, 1995) (Phillip Clark, "Russia's Satellite Launches on the Wane," *Jane's Intelligence Review,* November 1, 1996, p. 485). There are two other data-relay networks that may or may not be used for government/military communications, but are used commercially: SSRD-2 and SDRN. Both networks are divided into East, Central, and West zones. For *SSRD-2* this is denoted by VSSRD-2, CSSRD-2, and ZSSRD-2 (Russian word for East begins with a v-sound, etc.) and for SDRN this is denoted by ESDRN, CSDRN, and WSDRN. The Russian Satellite Communications Company (RSCC) is responsible for the operations of satellites of the Gorizont (9) and Express (2) satellite types. RSCC currently owns five large teleports and smaller regional monitoring stations all over Russia. "Russia—Liberalization of the Telecommunications Industry: An Overview," *International Market Insight Reports,* July 24, 1998.

77 In 1997, Russia had 30 operational spacecraft with a navigation mission ("Russian Space Activity," *Air Force Magazine,* August, 1998, p. 33.). The Russian analog to the Global Positioning System

(GPS/NAVSTAR) is the GLONASS system (20), planned to occupy three orbital planes 120 degrees apart with eight slots/plane. Phillip Clark, "Russia's Satellite Launches on the Wane," *Jane's Intelligence Review,* November 1, 1996. The Russians do not degrade accuracy of the satellite signal as does the US, and GLONASS does not encrypt the most accurate signal that it broadcasts. In 1994, it was reported that a Western businessman visited the Glonass command center at a high-security compound outside Moscow: "Once you get past the gate, it's like a whole city inside a fence. There are markets, apartments, schools . . . the closely guarded satellite-control center is dominated by enormous data screens and banks of computer terminals (Elliot Blair Smith, "Russia Positions System Against U.S. Satellite Program," *The Orange County Register,* July 17, 1994, p. K04.)." Air Force Magazine lists two other navigation satellite systems: Kosmos-military (6) and Kosmos-civil (4).

78 In 1997 Russia had four operational meteorological spacecraft: three Meteor and one Elektro (GOMS).

79 In 1997 Russia had eight operational early warning spacecraft: six in the first-generation *Oko* system and two in the second-generation Prognoz system.

The Oko system is Russia's first generation early warning system: orbits are reminiscent of the *Molniya*. When fully operating, the system comprises nine satellites with their orbital planes spaced 40 degrees apart in eccentric earth orbits. The Prognoz system (also described as a Russian scientific program designed to study the sun's activity and its influence on earth's magnetosphere) is Russia's second-generation early-warning system. The goal is to have three or four operational satellites in geosynchronous orbit, however technical problems are causing deployment to be delayed. Phillip Clark, "Russia's Satellite Launches on the Wane," *Jane's Intelligence Review,* November 1, 1996.

Chapter Five

1 Jeffrey Richelson, "Population Targeting and U.S. Strategic Nuclear Doctrine," in Desmond Ball and Jeffrey Richelson, eds., *Strategic Nuclear Targeting* (Ithaca: Cornell University Press), 1986, p. 237.

2 Richelson, "Population Targeting," pp. 238–40.

3 As described in Chapter Three, a P-95 circle is an approximation to the actual population distribution in a given urban area. Within the P-95 circle it is assumed that 95 percent of the associated population resides. A statistical analysis of demographic data for the European continent by the RAND Corporation in the 1970s yielded the following formula for the P-95 circle radius as a function of population: Radius (P-95, nautical miles) = 0.5125xln(1.3 + 0.2xP), were P is the population in thousands. One nautical mile equals 1852 meters. Thus a city of 10,000 would have a P-95 radius of 1.1 km, a city of 100,000 would have a P-95 radius of 2.9 km, a city of 500,000 would have a P-95 radius of 4.4 km and a city of 1,000,000 would have a P-95 radius of 5.0 km.

4 Robert McNamara, "Memorandum for the President; Subject: Recommended FY 1966-1970 Programs for Strategic Offensive Forces, Continental Air and Missile Defense Forces, and Civil Defense (U)," draft, December 3, 1964, p. 11.

5 Kenneth McGill, "USSTRATCOM/J53 War Plan Analysis," MSRR/MEL Users Conference, April 1999.

6 R. H. Craver, J. T. McGahan, E. Swick, M., K. Drake and J. F. Schneider, *The Feasibility of Population Targeting* (McLean, Virginia: Science Applications, 1979), Defense Nuclear Agency, Contract Number DNA 001-78-C-0061, June 30, 1979. Security Class: SECRET-RESTRICTED DATA (Released under FOIA with deletions), pp. 29–30.

7 *Ibid.*, p. 11.

8 McNamara, "Memorandum for the President," pp. 18-19.

9 *The Feasibility of Population Targeting,* p. 17.

10 *Ibid.*, p. 23.

11 *Ibid.*, p. 23.

12 *Ibid.*, p. 27.

13 The Russian population of 152 million is the number given in the 1999 LandScan data set. It is estimated that the current Russian population is probably about ten percent less than this figure and continues to decline at a significant rate.

14 Proponents of the Trident II system have argued that in the event of nuclear conflict with the Soviet Union, U.S. leadership should have the option of precise targeting as an alternative to overwhelming destructive use of nuclear weapons.

15 John M. Donnelly, "Air Force Okayed ICBM Upgrade Despite Unproven Accuracy," *Defense Week*, February 5, 2001, p. 1.

16 "Capabilities of Nuclear Weapons [U]," revised edition, TM 23-200, prepared by Defense Atomic Support Agency, Departments of the Army, Navy, and the Air Force, Washington, DC, November 1964.

17 The 19 NATO member countries currently include Belgium, Canada, Denmark, Germany, Greece, Italy, Luxembourg, Netherlands, Norway, Portugal, Turkey, United Kingdom, United States, French Military Mission, Spain, Iceland, Czech Republic, Hungary and Poland.

Chapter Six

1 From the late 1960s to the early 1990s, detailed and lengthy bilateral negotiations led to the SALT and START agreements. The treaties had extensive verification procedures as well as timetables for achieving upper ceilings or lower reductions. The treaties had the virtue of providing some boundaries and rules to a difficult and dangerous competition that was often on the verge of getting out of control. The chief drawbacks were that the negotiations were time-consuming; the internal policy process on each side was overly bureaucratic with every position and word needing widespread consensus.

These limitations would probably still be operative today and thus other approaches and initiatives are recommended. Nevertheless, while it is true that the Cold War is over, and that there are far different geopolitical conditions facing the U.S. and Russia, the competition between them and the vestigial suspicions they still have of one another have not totally disappeared. It would thus seem prudent to continue to implement the measures agreed to in the past treaties and not let the treaty regime unravel, especially the Anti-Ballistic Missile Treaty, a distinct possibility if certain choices are made.

2 George W. Bush, "New Leadership on National Security," May 23, 2000.

3 George W. Bush, "Remarks to Students and Faculty at National Defense University," Fort Lesley J. McNair, Washington, D.C. May 1, 2001.

4 "Missile Shield Argument Laughable, Russian Says," *Baltimore Sun*, May 15, 2001.

5 Erik Eckholm, "China Unconvinced as Missile Talks End," *New York Times*, May 16, 2001, p. A6.

6 Paul Mann, "Bush Team Rethinks Strategic Doctrine," *Aviation Week & Space Technology*, January 22, 2001, pp. 26–27.

7 Union of Concerned Scientists and MIT Security Studies Program, *Countermeasures, A Technical Evaluation of the Operational Effectiveness of the Planned US National Missile Defense System,* April 2000.

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