Chapter One

BACKGROUND AND MOTIVATION FOR IMPROVING NUCLEAR SAFETY

Since the dawn of the missile age, national security decisionmakers have sought to achieve a delicate balance between having a credible nuclear deterrent and ensuring the safety of nuclear weapons from unauthorized or accidental use. During the Cold War, when the United States and Russia perceived each other as a serious threat, the balance was weighted heavily toward the credibility of the deterrent, which was seen in terms of the ability to mount a massive and immediate nuclear retaliatory strike. Nevertheless, both countries took strong steps to reduce the risk of accidental or unauthorized use to the extent their nuclear postures would allow. Today, with the Cold War over, the ideological sources of the superpower conflict gone, and growing concern about the proliferation of weapons of mass destruction, a shift in the balance toward nuclear safety seems appropriate. The attacks of September 11, 2001, have underscored the need for this shift by pointing out the nature of the new nuclear threats that both the United States and Russia are likely to face. Moreover, Russia's reaction to the attacks and its support for the war on terrorism have demonstrated both the broad improvements that have been made in the relationship between the two former Cold War antagonists and the feasibility of pursuing such a shift.

This report provides a roadmap for how this shift toward nuclear safety could take place. First, it examines the types of scenarios that might lead to unauthorized or accidental use of nuclear weapons. It then considers contributing factors (such as nuclear forces being kept on high alert and short decision times) that might lead to unauthorized or accidental use. Finally, it develops a set of options for dealing with each contributing factor and weaves these options together to provide a phased approach for improving nuclear safety.

CONCERNS ABOUT THE CURRENT SITUATION

Today's concerns about nuclear safety are driven by several factors, including the nature of nuclear forces in both Russia and the United States, the status of Russia's early-warning system, Russia's economic difficulties, and several recent geopolitical trends.

Historical Asymmetries in Nuclear Forces

The characteristics of the U.S. and Russian nuclear forces, as they have evolved historically, have contributed to concerns about safety. Russia has traditionally been a land-based power, its nuclear forces heavily emphasizing intercontinental ballistic missiles (ICBMs) based in fixed silos hardened to withstand the effects of nuclear blasts. These missiles are reportedly ready to launch within a few minutes.

During the 1980s, the U.S. ICBM force was modernized to make it more accurate and survivable. The more significant development during that period, however, was the deployment of the Trident submarine, which represented a quantum leap in capability over previous generations of submarines. Its D5 missiles were as powerful and accurate as the best ICBMs, and it carried the W-88—the U.S. arsenal's most powerful warhead—specifically designed to attack and destroy hardened Russian silos. But the Trident also gave the United States something else: the ability to attack those hardened targets quickly. Trident missiles can reach their targets in 10 to 15 minutes if they are launched close to Russia; an ICBM would take at least 30 minutes. The Trident's combination of accuracy, lethality, and speed gave the United States the ability to deliver not only a retaliatory strike against Russian nuclear forces, but also a devastating first strike.

Russia responded to the increased accuracy of U.S. missiles during the 1980s by boosting the survivability of its ICBM force: it deployed some of its missiles on railcars and off-road trucks. When these mobile missiles were dispersed, they became almost as survivable as submarines. (When clustered together in their garrisons, however, they are far more vulnerable than silo-based ICBMs.) Russia also had a sizable nuclear submarine fleet, a portion of which remained at sea and thus was highly survivable. Hence, despite U.S. *technological* advances during the 1980s, both countries retained large and highly survivable nuclear forces.

Russia's Declining Nuclear Forces

The nuclear balance that had been established was fundamentally altered during the 1990s. While Russian forces deteriorated during and after the Cold War, making them increasingly vulnerable to a first strike, the United States retained much of its counterforce capabilities and deployed more Trident submarines with D5 missiles. This situation is likely to become more pronounced as Russian nuclear forces continue to decline in the first decade of the 21st century.

Today, Russia keeps all but a few of its mobile missiles in garrison, where they can be easily destroyed. Only one or two regiments (nine to 18 missiles) of its 360 road-mobile missiles are dispersed in the field at any one time. Its rail-based missiles are restricted to garrison by an order President Yeltsin issued in 1994. To boost the survivability of the mobile missiles it has in garrison, Russia could launch them through doors in the roofs of their garages before U.S. missiles arrive. As for Russia's ballistic missile submarines, only a small fraction of them (perhaps one or two) are kept at sea. The rest are in port, where they are very vulnerable to attack—one nuclear warhead can destroy most of the submarines at a base. Probably to improve their survivability, Russia's modern submarines are capable of quickly launching missiles from pier side that can hit targets in the United States. The final piece of Russia's nuclear triad, its bomber force, has always been kept at relatively low levels of readiness and is rarely used today. In the event of a significant surprise attack, few bombers are likely to survive.

By contrast, the United States retains a large and survivable nuclear force divided roughly equally among ICBMs, bombers, and submarines. Like Russia, the United States keeps its ICBMs (all based in silos) at high levels of alert, ready to launch within a few minutes. During the Cold War, the United States also kept its bombers on high alert, a portion of them either airborne or ready to take to the air within a few minutes. But since 1991, U.S. bombers have been taken off alert. Although roughly half of them still retain their nuclear mission, they spend much of their time training for or participating in nonnuclear conflicts. U.S. ballistic missile submarines provide the most survivable force for the United States and cause the most discomfort for Russia. Unlike Russia, the United States keeps a large portion of its submarines—roughly 60 percent—at sea, even today. This provides a large survivable force capable of delivering at least 1,000 warheads to targets in Russia.

In sum, whereas the United States has a large, survivable nuclear force with some 1,300 warheads deployed at sea, Russia has very few nuclear forces that could survive a surprise U.S. attack—only about 20 to 200 warheads—if it rode out the attack before launching a retaliatory strike. Although we do not know for certain, Russia may regard this number of nuclear forces as insufficient to deter the United States in a crisis, and may therefore be relying on a launch-on-warning strategy—a standard approach for maximizing the size of a retaliatory attack—that would allow it to retaliate with some 3,000 warheads. The launch-on-warning approach to nuclear warfare is, however, very destabilizing, because its proper execution requires an extremely rapid reaction—probably within 10 or 15 minutes. This means there is very little time to verify that early-warning information from satellites and land-based radars is correct.

Russia's Internal Problems

Three distinct internal problems, associated with Russia's economic collapse during the 1990s, exacerbate the concerns inherent in a nuclear strategy based on retaining forces on high alert and launching on warning:

1. Russia's social and economic problems have caused a substantial decline in its conventional force capabilities. Russia perceives its conventional forces as no match for the modern high-tech forces the West has demonstrated in the Persian Gulf, Kosovo, and Afghanistan. As a result, Russia increasingly relies on nuclear weapons to counter the West's conventional superiority and to deter its southern neighbors.

2. Russia's early-warning system has deteriorated significantly. Like the United States, Russia relies on a combination of satellite-based infrared sensors and ground-based radars to provide early warning of an attack and to reduce the chances of mistakes. Satellites provide the earliest warning of an attack; they detect the hot exhaust from missiles as they streak into space. Radars track the missiles as they get closer to the target. The problem is that both Russia's satellite and radar networks have holes in them today. Analyses by the Congressional Budget Office (CBO) and others have shown that Russian satellites currently have little, if any, ability to detect missiles launched from U.S. Trident submarines.[1] The satellite network observing U.S. ICBM fields has only one or two of its six satellites working today, which provides coverage for only about six hours a day. As for Russia's radar network, it, too, is incomplete: It has a large gap to the east and a smaller gap to the west through which Trident missiles could fly all the way to Moscow without being seen. The implications of Russia's blindness to nuclear attack are extremely troubling when combined with the compressed decision time required to execute a launch-on-warning strategy.

3. The general disorder in Russia today creates much uncertainty about the security and control of nuclear forces and materials. The far-flung deployments of Russia's nuclear forces and materials, the existence of separatist and terrorist groups, and the strong presence of organized crime in Russia combine to make this situation particularly dangerous.

U.S. Contributions to Nuclear Risk

The risk of accidental or unauthorized nuclear use is not created by Russia alone. The United States exacerbates the risk by continuing to posture its nuclear forces in a manner suitable to a nuclear damage limitation strategy—i.e., able to destroy a large portion of Russia's

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[1]See Geoffrey Forden, "Letter to the Honorable Tom Daschle Regarding Improving Russia's Access to Early-Warning Information" (Washington, DC: Congressional Budget Office), September 3, 1998, pp. 1–14; Geoffrey Forden, *Reducing a Common Danger: Improving Russia's Early Warning System* (Washington, DC: CATO Institute), May 3, 2001; and Pavel Podvig (ed.), *Russian Strategic Nuclear Forces* (Cambridge, MA: MIT Press), 2001, pp. 428–432.

nuclear forces before they can retaliate against the United States. This strategy involves having a large number of counterforce weapons deployed at the ready—in other words, ready to be launched within a few minutes or perhaps hours—in order to rapidly destroy a high percentage of Russia's nuclear forces. Similarly, the United States continues to patrol its attack submarines near the home bases and operating areas of Russia's increasingly vulnerable ballistic missile submarine force, where they can track the few of these submarines that Russia manages to put at sea. Furthermore, U.S. conventional forces in Iraq, Yugoslavia, and Afghanistan have demonstrated the ability to destroy hardened targets with nonnuclear, precision-guided weapons. Many Russian analysts are concerned that such weapons could be used against Russian nuclear targets. On the diplomatic and political side, the United States has shown a willingness to build a large national missile defense system even if doing so means abandoning the Antiballistic Missile Treaty. Russians remain concerned that a future U.S. national missile defense system, along with a large number of U.S. counterforce weapons (both nuclear and conventional), could severely limit, if not eliminate, Russia's nuclear deterrent.

OPPORTUNITIES FOR IMPROVING NUCLEAR SAFETY IN AN ERA OF IMPROVING RELATIONS

Fortunately, the end of the Cold War and the corresponding improvement in U.S.-Russian relations have created an opportunity for both countries to take steps to improve nuclear safety. Some steps in this direction have already been taken, such as sharp reductions in forces and the sharing of early-warning information, and further improvements in relations will make other measures possible as well. Moreover, steps taken to improve nuclear security can improve U.S.-Russian relations by reducing the relevance of nuclear weapons to the relationship.

The improvements in U.S.-Russian relations that have taken place so far are clearly indicated by both nations' reactions to the attacks of September 11, 2001. For the first time since the Second World War, the United States and Russia find themselves allied against a common foe. Russia's role in the war on terrorism has been substantial: encouraging the use of former Soviet bases in Central Asia, arming and funding Afghani groups opposed to the Taliban regime, and actively supporting U.S. initiatives in the international community. For the first time, it is possible to see a future in which Russia is a full-fledged member of the Euro-Atlantic community.

This new geostrategic environment poses difficult questions for U.S. and Russian strategists about deterrence requirements in the future and the appropriate size, posture, command and control infrastructure, and strategy for each nation's nuclear arsenal.

During the Cold War, the primary U.S. security goal was to deter a Soviet/Warsaw Pact invasion of Europe and a nuclear strike by the Soviet Union. The United States pursued this goal by building and deploying tens of thousands of nuclear weapons. Today, the greatest threat from Russia comes not from its strength but from its weakness. Russia's dysfunctional economy and eroded security systems have undercut its control of the vast stockpile of weapons, materials, and know-how accumulated during the Cold War, thereby increasing the risk that they could flow to terrorist groups or other hostile forces.

As Russia and the United States begin to explore the form and structure of their new deterrence postures, several features are likely to carry over from their Cold War postures.[2] First, both nations are

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[2]We have attempted to avoid prejudging what nuclear strategy and posture are appropriate for the new strategic era. While not taking a stance on nuclear strategy issues, we do highlight nuclear safety options that *do* and *do not* require a change in nuclear strategy and posture. It is also important to point out that many steps can be taken to improve nuclear safety in the absence of a wholesale change in U.S. nuclear strategy.

However, we feel it important to say that the long-running U.S. nuclear strategy of damage limitation (i.e., the requirement to destroy as many Russian nuclear weapons as possible before they can be used to retaliate against the United States) would be a serious impediment to improving nuclear safety. A damage limitation strategy necessitates a nuclear posture that includes a large number of counterforce weapons ready to launch within minutes to rapidly destroy Russia's nuclear forces. For example, a Trident submarine must be within a certain distance of its designated targets with its missiles prepared to fire within minutes if it is to destroy Russian ICBM forces before they can be launched. This posture is directly at odds with attempts to assure Russia it can move to a more relaxed nuclear posture and thereby decrease the risk of an unauthorized or accidental nuclear launch.

Whether a damage limitation nuclear strategy is necessary today to deter Russia from attacking the United States is a point of serious contention among nuclear strategists both within and outside the U.S. government. Some strategists contend that likely to retain some kind of retaliatory deterrent. Although the new strategic environment is vastly different from that of the Cold War, nuclear weapons remain the ultimate deterrent against nuclear attacks against the homeland or important regional allies. Second, the historical asymmetries in Russian and U.S. nuclear forces and operating practices are likely to persist for the foreseeable future.

Despite the likely persistence of these Cold War features, however, new factors are creating the potential for a very different and greatly improved nuclear relationship. The most important of these new factors is the improving and increasingly cooperative nature of U.S.-Russian relations. Ten years after the Cold War, it seems highly anachronistic that both nations retain thousands of nuclear weapons on high alert and tolerate the associated risk of unauthorized and accidental nuclear use. Another important factor is the changing nature of the strategic threat confronting the United States as a result of the September 11 terrorist attacks. Although the current crisis does not represent the full spectrum of strategic issues the United States is likely to face during the 21st century, it will probably cause strategic thinkers to reevaluate the role of nuclear weapons in this new geostrategic era.

At the same time, the obstacles to reducing the role of nuclear weapons in the U.S.-Russian relationship remain formidable. Despite recent cuts in their nuclear arsenals, both countries retain very large numbers of nuclear forces. Even if all reductions recently agreed to in

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a more flexible nuclear doctrine is more appropriate today, one that emphasizes countervalue attacks in the event of hostility with another nuclear-armed state, which could be Russia, China, or a rogue state. These analysts argue that a damage limitation strategy is inappropriate because of the vastly improved relations between the United States and Russia and because many features that led to the introduction of a counterforce strategy in the first place disappeared with the end of the Cold War. For example, the possibility of conventional war between Russia and the United States is now regarded as such a remote possibility that the Pentagon has completely removed it as a planning scenario for sizing and modernizing U.S. conventional forces. The analysts suggest that nuclear planning should be similarly altered, directed away from specific scenarios focused on Russia and toward more general nuclear scenarios. Public statements by officials in the Bush administration suggest that the 2001 Nuclear Posture Review took steps in this direction.

We do not know at this time whether the United States still retains a damage limitation strategy. However, U.S. forces have been designed and operated for such a strategy, and demonstrating a retreat from that strategy will be difficult in the absence of overt changes to the postures or the forces themselves.

the Moscow Treaty are achieved by 2012, the United States and Russia will still retain around 2,000 strategic nuclear weapons each. In addition, a deep level of mistrust remains from the Cold War confrontation and is stoked by continuing disagreements about important security issues, such as NATO expansion, the role of the two powers in Central Asia, and the future of Iraq. These disagreements are unlikely to dissipate quickly, although recent events indicate a willingness on the part of the United States and Russia to explore a new framework for their relationship.

STUDY APPROACH

Our study approach entailed defining a series of phased steps for improving nuclear safety that begin today and go out to roughly 2020. The approach provides both an overall strategy for improving nuclear safety and specific policy steps, on a timeline, to minimize the risk of accidental or unauthorized nuclear use. We also sought to integrate our proposed Nuclear Safety Initiative with two major strategic policies of the United States: improving U.S.-Russian relations and redefining U.S. deterrence needs in light of a rapidly evolving geostrategic environment. At the beginning of the timeline are immediate and near-term steps that could be taken to improve nuclear safety unilaterally or through rapid mutual agreement. These initial steps are designed to build confidence and trust between the two nations. If these steps are successful, more-extensive steps could be taken, in the medium term, to build toward a long-term goal of significant improvements in nuclear safety coupled with a cooperative U.S.-Russian relationship.

One of the difficulties in designing a set of strategies and policies for improving nuclear safety is the broad, cross-cutting nature of the problem. Nuclear safety for Russia and the United States touches on such pivotal and controversial issues as nuclear strategy, the readiness and posture of U.S. and Russian nuclear forces, and the changing nature of U.S.-Russian relations. It also involves multiple federal agencies. Addressing the problem of nuclear safety will therefore require *direct* Presidential leadership and commitment. Within the U.S. government, this could be accomplished two ways. First, it could be done through a National Security Council (NSC) process initiated by a Presidential Directive (PD). The Appendix of this report outlines what might be included in such a PD if President Bush decided to make nuclear safety a priority of his administration. Second, it could be accomplished by the President and a few key advisors making the decisions, thereby avoiding the interagency process altogether—much like the former President Bush did with the unilateral reductions in 1991. Each model has advantages and disadvantages.

What we have done in this report is to present a limited version of the analyses that the Department of Defense and other agencies (or Presidential advisors) might perform to provide the President with various options for reducing the risk of accidental or unauthorized nuclear use. The first item the advisors or agencies would have to consider is the scope of the problem: What is the range of possible scenarios that might lead to accidental or unauthorized nuclear use? Chapter Two covers this first step, exploring the possible scenarios in which an incident of nuclear use might begin. It then goes on to the next step: Identify and assess the underlying factors that might contribute to possible nuclear use (e.g., launch readiness of nuclear forces, perceived vulnerability of nuclear forces or command and control systems to a nuclear first strike, adequacy and reliability of early-warning information, and the amount of time leaders have to decide whether or not to respond to a perceived nuclear attack).

The next step in the process is to define the criteria to be used in evaluating the possible approaches for improving nuclear safety. Because of their uniquely destructive properties, nuclear weapons have both a military and a symbolic role in global affairs, which implies that nuclear safety options (particularly those that change the size, readiness, and operation of nuclear weapons) will affect a broad range of issues. Therefore, an evaluation of the pros and cons of a particular nuclear safety approach should include its effect on U.S.-Russian relations, efforts to prevent the proliferation of weapons of mass destruction, and current U.S. strategies and targeting plans. Chapter Three defines such criteria, as well as criteria directly related to the goal of improving nuclear safety.

Chapter Four examines a wide range of potential approaches, or options, for improving nuclear safety. We selected 10 options for detailed investigation. Each is discussed in a separate section, which includes background on the particular nuclear risks the option is designed to help solve, as well as an introduction to the option itself. Specific technical and operational details on the option are outlined, and the option is evaluated using the criteria established in Chapter Three.

Chapter Five sets forth those 10 options we recommend as the most promising and provides a phased timeline for implementing them. Our recommendations include possible immediate and near-term steps to reduce nuclear dangers and to build confidence and trust in U.S.-Russian relations. Additional steps, in the medium and long term, that move toward the twin long-term goals of a strengthened and cooperative U.S.-Russian relationship and a significantly reduced risk of accidental or unauthorized use, are then described.

All of the potential options are at best only steps toward an ultimate solution of the nuclear safety problem: a U.S.-Russian relationship where neither country views the other as a nuclear threat and postures its nuclear forces accordingly. The current relationship between Britain and France illustrates this end state. Both of these countries are nuclear powers, and they do not have the same interests on all issues. However, neither country would ever consider using nuclear weapons or even military force against the other to settle a dispute. Although this possibility seems remote today for the United States and Russia, the end of the Cold War and the corresponding improvements in relations have created the opportunity for both countries to start the process that might lead to this end state.

Chapter Two

POSSIBLE SCENARIOS FOR ACCIDENTAL OR UNAUTHORIZED NUCLEAR USE

A variety of scenarios could result in the accidental or unauthorized use of nuclear weapons. This chapter begins by analyzing the different types of possible scenarios, giving several examples of each one. Some of the examples are real world experiences that illustrate the types of problems that might lead to accidental or unauthorized use; others are fictional situations that demonstrate how a combination of factors might lead to nuclear use. The chapter then considers all of the underlying factors that might contribute to accidental or unauthorized nuclear use in these scenarios. Only after understanding these factors can solutions be designed to reduce nuclear risks.

POSSIBLE SCENARIOS

Because our goal was to understand the underlying causes for accidental or unauthorized nuclear use, we tried to capture as many of scenarios as possible. We grouped our results into three basic types of scenarios, as shown in Figure 2.1. We believe this set of eight types encompasses the full range of possible scenarios involving accidental or unauthorized use of nuclear weapons.

Although none of these types of scenarios is very likely, the tremendous destructive capacity of nuclear weapons makes the risk of even one of them occurring unacceptably high. Furthermore, if one were to occur, it is unlikely that it would result directly from a single un-

Type I: Unauthorized Launch
- Intentional launch by rogue commander or terrorist

Type II: Launch by Mistake
- Training accident
- System malfunction

Type III: Intentional Launch Based on Incorrect Information
- Malfunction of early-warning system
- Incorrect interpretation of nonthreatening event
- Misperception of nuclear attack by third country or terrorists
- Misperception of accidental nuclear detonation on own territory
- Misinterpretation of simulated training attack as real attack

Figure 2.1—Possible Scenarios for Accidental or Unauthorized Nuclear Use, by Type

derlying factor. It is more likely that a combination of factors would be involved. We explore the possible scenarios below, grouped according to type.

Type I Scenarios: Unauthorized Launch

Sustained economic hardship and other internal difficulties have created uncertainty about the stability of Russia's system for maintaining strict control of its nuclear forces and materials. Although the situation may have improved over the past couple of years, Russia is a more chaotic place than it was during the Soviet period. During peacetime, this may not be a serious problem; but under the pressure of a domestic or international crisis, Russia's command and control of its nuclear forces may face problems.

The two fictional scenarios described next illustrate the kinds of crises that might lead to an unauthorized launch of nuclear weapons. The first involves terrorists; the second involves a rogue commander (i.e., one who takes control of the nuclear forces he commands).

In the first, Russian-Chinese relations become increasingly hostile between 2002 and 2007. In 2007, increasing nationalism in China leads to a border dispute with Russia, and both sides mass troops on the border. Russia's conventional forces in the Far East are no match for China's, so Russia heightens the alert level of its nuclear forces. One of the measures it takes is to disperse its mobile ICBM force into the field.

While Russia's mobile ICBMs are in the field, a terrorist organization supported by sympathizers within the Russian military seizes control of a mobile ICBM. The terrorists gain access to launch codes either from sympathizers in the military or by overcoming protection systems during the confusion of a crisis.

The second fictional scenario involves a period of internal political turmoil. Perhaps there is a disputed Russian presidential election, during which military supporters of one candidate seize control of a Russian ballistic missile submarine, ordering all outsiders to stop interfering in Russian domestic affairs. The submarine's captain, fearing that the United States will send attack submarines to destroy his submarine, warns the United States to keep its attack submarines out of his patrol area. He threatens to launch his missiles against the United States if it tries to attack.

Type II Scenarios: Launch by Mistake

In this type of scenario, one or more missiles are launched by mistake during a training exercise or because the command and control system malfunctions. Because the nuclear force training does not involve the use of actual weapons, the probability of an accident is very low. The consequences of such a mistake, however, would be catastrophic.

A real-life example of what can occur during training is provided by an incident that happened on November 9, 1979, when the computer displays at North American Aerospace Command, the Pentagon's National Military Command Center, and the Alternative National Military Command Center all showed a massive Soviet nuclear strike aimed at U.S. nuclear forces and command and control infrastructure. A conference call among the command posts was convened and the launch control centers at the U.S. ICBM facilities were given preliminary warnings that the United States was under nuclear attack. The U.S. continental air defense was also alerted, and at least 10 fighters took off to defend U.S. airspace against possible attacks by Soviet nuclear bombers.[1] Even the President's airborne command center was launched without the President on board.

A crisis was averted when the raw data from the U.S. early-warning launch detection satellites showed no signs that the United States was under nuclear attack. It was later determined that a realistic training tape had been mistakenly inserted into the computer running the nation's early-warning computer programs. To avoid repeating the mistake, the United States trains its personnel in response procedures on a system completely separate from the real missile warning system.

Type III Scenarios: Intentional Launch Based on Incorrect Information

The Type III scenarios (see Figure 2.1) all involve national leaders authorizing nuclear retaliation after being convinced by a faulty reading of the situation that the country is under nuclear attack. This type of scenario could occur either during day-to-day operations or in the midst of a serious crisis. Concern about this kind of scenario has been heightened since the end of the Cold War because of the steady deterioration of Russia's early-warning systems and the increased vulnerability of Russian forces to a disarming first strike by the United States.

Of the various scenarios involving intentional launch based on incorrect information, we illustrate four. The first two are real-life examples of problems associated with malfunctioning early-warning systems. They illustrate the dangerous connection between nuclear forces being kept on high alert, short warning times, and faulty early-warning systems. The second two are fictional situations illustrating what can happen when a nuclear attack by a third party or an accidental nuclear detonation is misperceived as an attack on Russia or the United States.

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[1]See Geoffrey Forden, *Reducing a Common Danger: Improving Russia's Early Warning System* (Washington, DC: CATO Institute), May 3, 2001.

The first example is an incident that occurred in 1995 when Russia was suddenly faced with an unknown ballistic missile headed toward outer space near Russian territory. Early on the morning of January 25, 1995, Russia's early-warning radar at Olenegorsk detected a ballistic missile streaking toward space from somewhere in the Barents Sea area, where U.S. ballistic missile submarines are known to operate. Within minutes, Russian military commanders had placed Russia's nuclear forces on heightened alert, and for the first time, then President Boris Yeltsin activated his "nuclear football"—the briefcase containing the codes for launching Russia's nuclear forces.[2] He then stood by, waiting to launch Russia's nuclear weapons at the United States if his military commanders determined that the attack was real.[3] After several tense minutes, Russian early-warning satellites determined that no U.S. ICBM had been launched, reinforcing the view of some Russian officials that it was a false alarm. Russian officials reportedly believed that the United States was extremely unlikely to launch a nuclear attack that did not involve using both its Trident submarines and its ICBMs.

The missile turned out to be a NASA sounding rocket, launched from northern Norway toward the North Pole to conduct research on the polar climate. Even though the missile was not heading toward Russia, it could have been a so-called precursor attack in which the United States was exploding a nuclear weapon high in the atmosphere to blind Russia's early-warning radars to a large nuclear attack that would arrive minutes later.[4] This incident occurred in spite of Russia's having been notified more than a month earlier that the launch would take place, as required by agreement. Through a combination of errors and inadequate procedures in Norway, Russia, and the United States, the notification evidently never made it to Russia's

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[2]See Bruce Blair, Harold Feiveson, and Frank von Hippel, "Taking Nuclear Weapons Off Hair-Trigger Alert," *Scientific American*, November 1997; and Forden, *Reducing a Common Danger*.

[3]Interview with Bruce Blair for *Frontline*, "Russian Roulette," aired February 23, 1999.

[4]Theodore A. Postol, "The Nuclear Danger from Shortfalls in the Capabilities of Russian Early Warning Satellites: A Common Russian-U.S. Interest for Security Cooperation," presentation to Carnegie Endowment for International Peace, February 26, 1999, pp. 17–34.

Strategic Rocket Forces.[5] This episode was what galvanized much of the effort in the United States to reduce the alert rates of nuclear forces and to improve Russia's access to early-warning information.

In the second real-life case, Russia's early-warning system mistakenly indicated that the United States had launched several ICBMs from its continental missile fields.[6] On the evening of September 26, 1983, Lt. Col. Stanislav Petrov, the officer in charge of operating Russia's spaced-based early-warning system, spotted on his computer screen what looked like the launch of several missiles from U.S. ICBM fields. Petrov was getting his data from Russia's new Oko satellites operating in highly elliptical earth orbit. It is unknown whether Petrov realized that the Oko satellites would register false positives when sunlight reflected off high-altitude clouds, a condition that was occurring that day.

Petrov reported that he never passed the warning to his superiors because he quickly concluded it was a false alarm. He said his early-warning system indicated that only five U.S. missiles had been launched, and he thought it highly unlikely that the United States would begin a nuclear conflict with such a limited strike.[7]

The third and fourth situations involve the explosion of a nuclear weapon in or near Russia or the United States, either by terrorists or by accident. The command and control structure of either nation would be severely tested if an actual nuclear explosion occurred on its territory. Quickly, within the first few minutes or hours, national leaders would have to determine whether the explosion was an attack, and, if so, who or what was behind it and how extensive it was. During those first few moments, critical mistakes could be made in trying to arrive at these determinations. Nuclear postures and strategies that require launch on warning are particularly dangerous in these types of scenarios.

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[5]"Will New Notification Procedures Ensure There Is No Repeat of the 1995 Norwegian Incident?" *De-Alerting Alert*, Issue 1, October 1997.

[6]David Hoffman, "I Had a Funny Feeling in My Gut," *Washington Post*, February 10, 1999, p. A19.

[7]Ibid.

Two fictional examples of such scenarios, in which a nuclear event could lead to an intentional launch based on incorrect information, are given next. These are more likely to occur if a country's early-warning system has large holes in it, its nuclear forces are not survivable, or the incident occurs during a crisis:

1. A terrorist organization explodes a nuclear weapon within a major metropolitan area of one of the countries. The chaos and confusion caused by the nuclear blast leads the national command authority to believe the country is under attack by the other country. It launches a retaliatory nuclear strike.
2. An accidental nuclear detonation occurs in one country while nuclear weapons are being transferred onto a submarine or ICBM. The confusion surrounding the incident leads the national command authority to conclude the country is under attack and to launch a retaliatory nuclear strike against the other country.

FACTORS CONTRIBUTING TO POSSIBLE NUCLEAR USE

If an accidental or unauthorized launch were to occur, it is unlikely that a single factor would have directly led to it. It is more likely that a combination of factors would be needed, including a tense nuclear relationship between the United States and Russia, the presence of a large number of nuclear forces maintained in a manner that makes them ready for immediate launch, and a sudden crisis or accident that creates false impressions and errors in judgment.

We tried to determine all of the underlying factors that might cause any one of the scenarios to occur. Figure 2.2 lists these factors by scenario type. We then pulled out the seven distinct factors in the list (see Figure 2.3). Note that several factors can contribute to more than one scenario.

Using the list of seven factors, one can clearly identify the issue that efforts to improve nuclear safety should address. We used that list to develop potential options for reducing nuclear risk in Chapter Four. Although our focus is on the United States and Russia, the list of factors could be applied to any nuclear state.

Type I Scenarios: Unauthorized Launch
- Inadequate security and control of nuclear forces and weapons
- Nuclear forces kept at high day-to-day launch readiness

Type II Scenarios: Launch by Mistake
- Inadequate security and control of nuclear forces and weapons
- Inadequate training precautions
- Nuclear forces kept at high day-to-day launch readiness

Type III Scenarios: Intentional Launch Based on Incorrect Information
- Nuclear forces kept at high day-to-day launch readiness
- Perceived vulnerability of nuclear forces or command and control systems
- Inadequate early-warning information
- Short decision times
- Deterrence doctrine or posture reliant on launch on warning or launch under attack

Figure 2.2—Contributing Factors for Each Type of Scenario

1. Nuclear forces kept at high day-to-day launch readiness
2. Perceived vulnerability of nuclear forces or command and control systems
3. Inadequate early-warning information
4. Short decision times
5. Deterrence doctrine or posture reliant on launch on warning or launch under attack
6. Inadequate security and control of nuclear forces and weapons
7. Inadequate training precautions

Figure 2.3—Seven Factors Contributing to Possible Nuclear Use

The remainder of this section examines each factor in detail.

Factor 1: Nuclear Forces Kept at High Day-to-Day Launch Readiness

Today, the United States and Russia keep their nuclear forces at high levels of launch readiness. But they have taken very different approaches to how they structure and posture their forces (see description in Chapter One).

This high level of launch readiness in both countries contributes to nuclear dangers in several ways. First, both countries having thousands of nuclear weapons ready to launch within minutes leaves very little time in a crisis for either one to decide whether it is under attack before it must decide how to respond. If the enemy has launched a first strike and the nation's leaders hesitate to make a decision, their forces will be destroyed. This is a particular problem for Russia today, because its forces are smaller and less survivable than the U.S. forces. Russia would have only a small force left if it waited to absorb a U.S. first strike before retaliating. Second, high launch readiness lowers the threshold for accidental nuclear use because it reduces the number of steps needed to launch the missiles. Third, if a rogue commander or a terrorist organization were able to take over ICBM launchers or a ballistic missile submarine, it would have all the components needed for launch except the authorization codes, which are controlled by higher authorities at separate locations. If it could gain access to the launch codes through a well-placed source within the nuclear command authority, it would need to maintain control over the missiles for only a short time in order to launch them.

Factor 2: Perceived Vulnerability of Nuclear Forces or Command and Control Systems

Another factor that contributes to nuclear safety concerns is the awareness of the Russian leadership that its nuclear forces and command infrastructure are vulnerable to a massive U.S. strike utilizing both nuclear and conventional weapons. Such a strike could, in theory, leave Russia with only a very modest retaliatory capability of a hundred or fewer warheads to launch against the United States if it opted to "ride out" a nuclear attack. In response to this concern, Russia has very likely placed much greater reliance on a launch-on-warning strategy that requires it to launch its forces before incoming warheads arrive—i.e., within 25 to 30 minutes if the attack consists of ICBMs coming from the United States, or within as little as 10 to 12 minutes if the attack comes from Trident submarines located a few thousand kilometers off the Russian coast.[8] This strategy could be extremely dangerous during a crisis, because Russia's leaders would have only a few minutes to determine whether what was occurring was a nuclear attack or, instead, a false alarm caused by a malfunction in their early-warning system or a misinterpretation of an actual event. According to some analysts, this is the reason why the January 1995 incident was so dangerous.[9]

There are several interconnected pieces to this problem. First, Russia's economic and financial crisis has severely limited the amount of money going to the armed forces, including Russia's nuclear forces. As a result, Russia has very few forces that would likely survive a surprise attack. Reports indicate that Russia has at most one to two regiments of nine single-warhead road-mobile ICBMs deployed in the field[10] and one to two ballistic missile submarines at sea, each carrying 64 warheads.[11] For a three-month period in 1998, Russia had no ballistic missile submarines at sea, according to one report.[12] Second, the United States continues to posture its nuclear forces in a manner suggestive of an offensive counterforce "damage limitation" strategy—i.e., a strategy to destroy a large portion of Russia's nuclear forces before Russia could retaliate against the United States. Such a strategy requires that a large number of accurate, powerful counterforce weapons be deployed at the ready—meaning they could be launched within minutes—in order to rapidly destroy a high percentage of Russia's nuclear forces. In addition, the United States reportedly continues to patrol its attack submarines near the patrol

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[8]Blair, Feiveson, and von Hippel, "Taking Nuclear Weapons Off Hair-Trigger Alert"; and Bruce Blair, *Global Zero Alert for Nuclear Forces* (Washington, DC: Brookings), 1995, pp. 43–56.

[9]Blair, Feiveson, and von Hippel, "Taking Nuclear Weapons Off Hair-Trigger Alert"; Blair, *Global Zero Alert*, pp. 43–56; and Postol, "The Nuclear Danger from Shortfalls," pp. 4–6.

[10]Blair, *Global Zero Alert*, pp. 48, 64.

[11]Robert S. Norris and William M. Arkin, "Nuclear Notebook: Russian Nuclear Forces, 2001," *Bulletin of the Atomic Scientists*, Vol. 57, No. 3, May/June 2001, pp. 78–79.

[12]John Downing, "Russian SSBN Patrols Halted for Three Months," *Defense Week*, January 11, 1999, p. 1.

areas of Russia's increasingly strategic submarine force. Third, U.S. conventionally armed air and cruise missile forces in Iraq and Yugoslavia have demonstrated their ability to destroy hardened targets with nonnuclear precision-guided weapons. Russian analysts are concerned that these weapons could be used against Russia's nuclear forces and its command and control infrastructure.

Factor 3: Inadequate Early-Warning Information

The breakup of the Soviet Union and Russia's economic and budgetary problems have caused Russia's early-warning system to badly deteriorate. Analyses conducted by the Congressional Budget Office (CBO) and several U.S. and Russian analysts over the past several years suggest that Russia's early-warning system is in decay, particularly its space-based launch detection system.[13] This trend shows no signs of halting.

Like the United States, Russia relies on a combination of infrared satellite-based sensors and ground-based radars to provide early warning of an attack and to reduce the chances of mistakes. The satellites provide the earliest warning of an attack; they detect the hot exhaust from missiles as they fly into space. The land-based radars track the missiles as they get closer to the target.

Russia's Space-Based Early-Warning System. Russia has relied on two constellations of space-based sensors to detect U.S. missiles as they are launched (see Figure 2.4).[14] The primary one, called Oko, is designed to provide full-time surveillance of rocket launches from ICBM fields in the central United States. For a variety of technological and bureaucratic reasons, Russia has never mastered the technology that would allow its satellites to look straight down at the earth and detect missile plumes (the hot gases that escape from a

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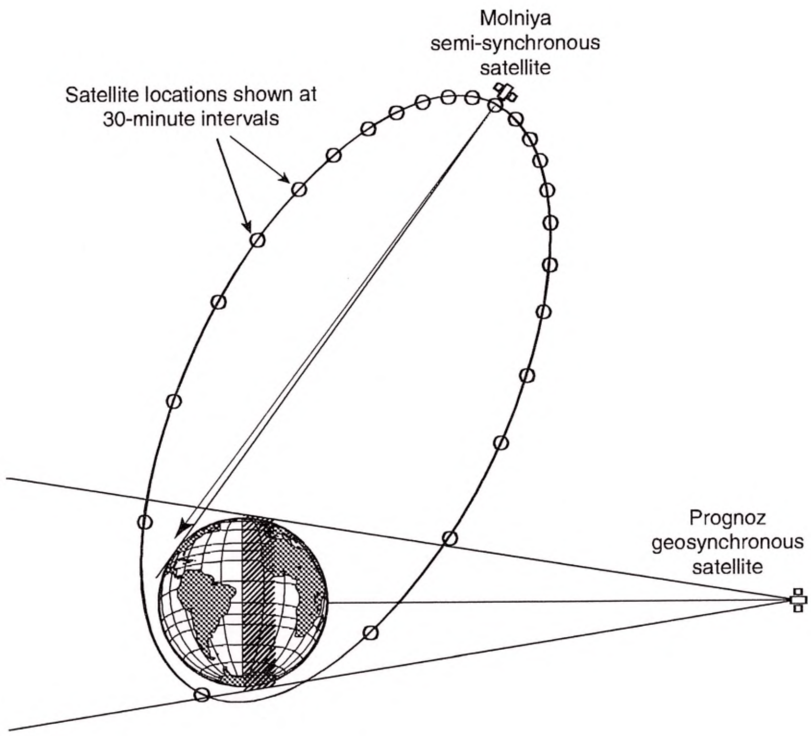
[13]Geoffrey Forden, "Letter to the Honorable Tom Daschle Regarding Improving Russia's Access to Early-Warning Information"(Washington, DC: CBO), September 3, 1998; Podvig, *Russian Strategic Nuclear Forces* (Cambridge, MA: MIT Press), 2001; and Postol, "The Nuclear Danger from Shortfalls."

[14]See Paul Podvig, "The Operational Status of Russian Space-Based Early Warning System," *Science and Global Security*, Vol. 4, 1994, pp. 363–384, and Podvig, *Russian Strategic Nuclear Forces*, pp. 420–435.



SOURCE: Postol, 1999.

Figure 2.4—Russia's Molniya (Oko) and Geosynchronous (Prognoz) Early-Warning Satellites

rocket motor when it is burning).[15] So Oko satellites must observe the missiles against the cold background of space, a simpler solution but one that allows each satellite to view missiles only above a small portion of the earth. For each satellite to observe U.S. ICBM fields for as long as possible, Oko satellites are placed in highly elliptical, or so-called Molniya, orbits.[16] As a result, Russia needs at least six satellites to provide constant coverage of the central United States, where U.S.

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[15]Forden, *Reducing a Common Danger*, pp. 11–12; and Postol, "The Nuclear Danger from Shortfalls," pp. 44–99.

[16]Forden, *Reducing a Common Danger*, pp. 11–12.

ICBMs are based, and those satellites must be replaced every few years.[17]

Furthermore, the Oko constellation provides little, if any, coverage of the oceans, where the bulk of U.S. forces are deployed today on submarines. Compare this with the United States, whose look-down satellites, called the Defense Support Program (DSP), can see a full one-third of the globe because the United States has mastered the technology of looking straight down at the earth.

Since 1984, Russia has complemented the Oko constellation with a system of satellites based in geosynchronous orbits, the same type of orbits the United States uses for its DSP satellites.[18] In theory, satellites in this type of orbit can see the entire one-third of the earth below them. But the placement of the Prognoz satellites suggests their ability to look down is very limited, and that they are instead designed primarily to watch missile fields in the central United States and to provide a redundant system for the Oko constellation.[19] Information from Russian experts indicates that these satellites may be able to look down, but only at areas of the ocean much smaller than would be needed to provide coverage of the broad areas where U.S. ballistic missile submarines could patrol.[20] Today, however, not one of the geosynchronous satellites is operational.[21] As a result, Russia has little, if any, ability to detect the launch of missiles from Trident submarines.

In January 1995, when the incident involving the launching of the sounding rocket from Norway occurred, Russia had nine Oko satellites in orbit at locations suggesting they were all operational, which would have given Russia 24-hour coverage of U.S. ICBM fields.[22] (The top panel of Figure 2.5 shows the nine Oko satellites as they were on January 25, 1995, closely following each other as they made their unique orbit around the earth.) Russia also had one Prognoz

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[17]Ibid.

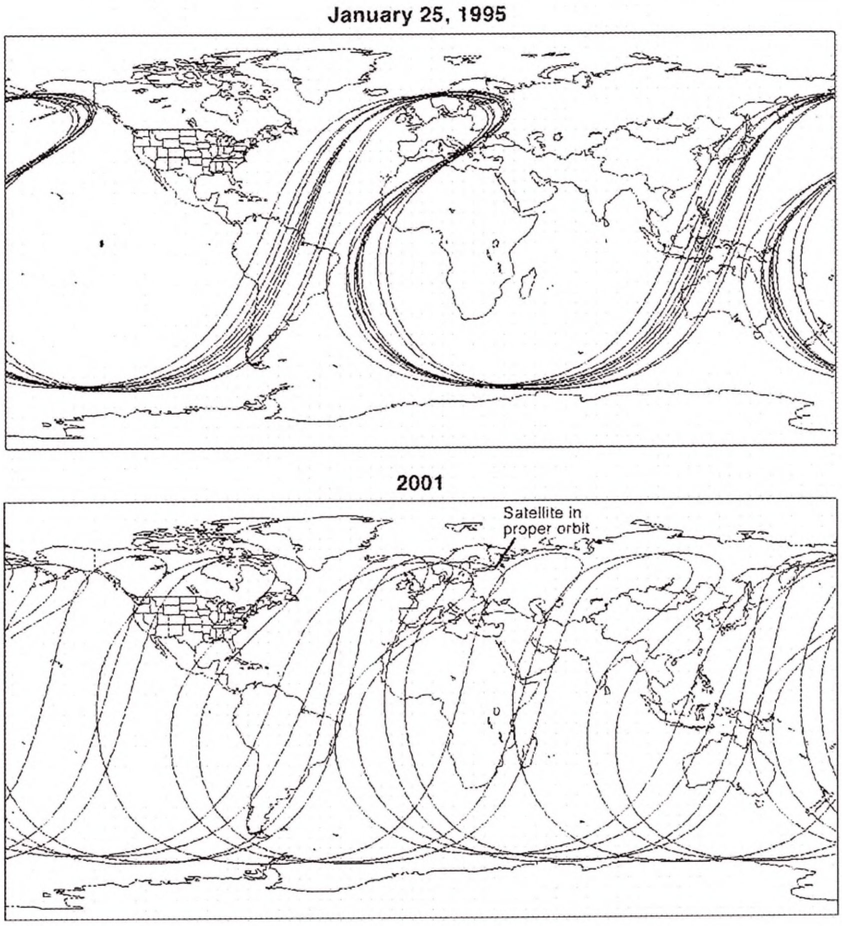
[18]Podvig, *Russian Strategic Nuclear Forces*, p. 432.

[19]Forden, *Reducing a Common Danger*, p. 13.

[20]Postol, "The Nuclear Danger from Shortfalls," pp. 44–99.

[21]Podvig, *Russian Strategic Nuclear Forces*, p. 432.

[22]Forden, *Reducing a Common Danger*, p. 12.



SOURCE: Forden, 2001.

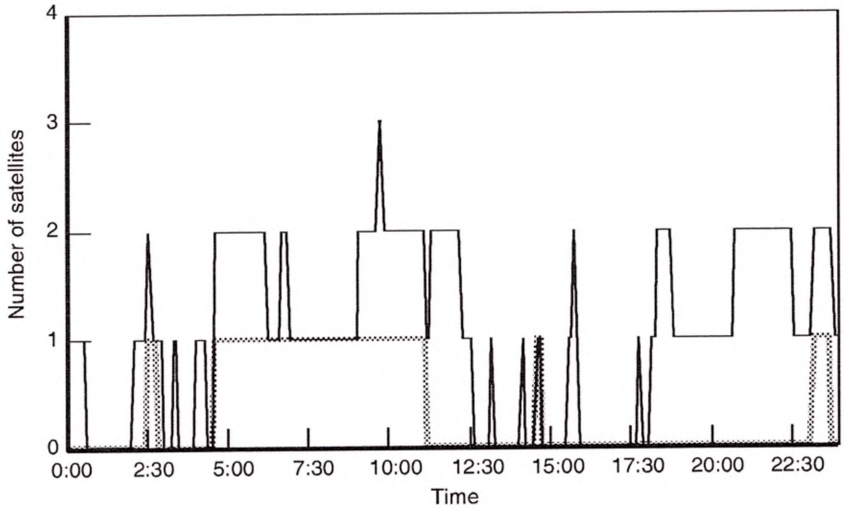
Figure 2.5—Ground Tracks of Russian Oko Satellites on January 25, 1995, and in 2001

satellite in orbit that was in position to monitor U.S. ICBM fields and possibly small areas of the Atlantic Ocean.[23] The around-the-clock

[23]Postol, "The Nuclear Danger from Shortfalls," p. 72.

coverage led some analysts to conclude that Russia was able to determine that the sounding rocket was not part of a larger attack because it could see no evidence of launches from U.S. missile fields and its commanders believed that the United States would include its ground-based ICBMs in any attack launched on Russia.[24]

The condition of Russia's space-based early-warning system has deteriorated significantly since 1995.[25] By 1998, only four Oko satellites remained in orbit; and as shown in Figure 2.6 (see the thin line), CBO's analysis found that the constellation could provide at most 17 hours of coverage of U.S. ICBM fields. This assessment is optimistic, however, because it assumes that all the satellites still in orbit continued to function, and Russia is known to allow nonfunctioning



SOURCE: Geoffrey Forden, personal communication.

Figure 2.6—Daily Coverage of U.S. ICBM Fields by Russian Molniya (Oko) Satellites, August 1998

[24]Forden, *Reducing a Common Danger*, p. 14.

[25]Ibid, p. 12.

satellites to drift from their original orbits. A look at the orbits of the five Oko satellites in orbit in 2001 (see bottom panel of Figure 2.5) suggests that only one is in the proper orbit and continues to function. What's more, Russian experts indicate that none of Russia's Prognoz geosynchronous satellites were operational in 1998. If this is true, Russia could view U.S. missile fields for only six or seven hours each day in 1998 (see the thick line in Figure 2.6) and had no ability to view Trident patrol areas.

Today, the situation is even worse. Russia has not launched any early-warning satellites since 1998. In addition, a fire in the ground control center for the Oko satellites in May 2001 left the constellation drifting uselessly in space, although control may have been restored recently.[26]

Russia's Ground-Based Early-Warning System. Russia's network of early-warning radars also has significant coverage gaps, although not as severe as those in its space-based early-warning system. Russia relies on an extensive network of ground-based radars as a key element of its early-warning system. But these radars, like those deployed by the United States, are limited in what they can see by the curvature of the earth. They thus cannot detect incoming missiles until much later in their flight than space-based detection systems can, which means they leave much less time for commanders to determine whether there is an attack and to decide whether to retaliate.

Today, there are several problems with Russia's early-warning radar network.[27] First, the second-generation system of large phased-array radars (LPARs) was never completed. Radars planned for construction at Mishalevka and Balkhash were never built, and the one under construction at Krasnoyarsk was torn down because it was in violation of the Antiballistic Missile (ABM) Treaty. In addition, Russia lost one of its completed LPARs following the breakup of the Soviet Union. Opposed to a continued Russian military presence in its now independent state, the Latvian government shut down the Skrunda radar in 1998. All of these incidents have left Russia's current early-

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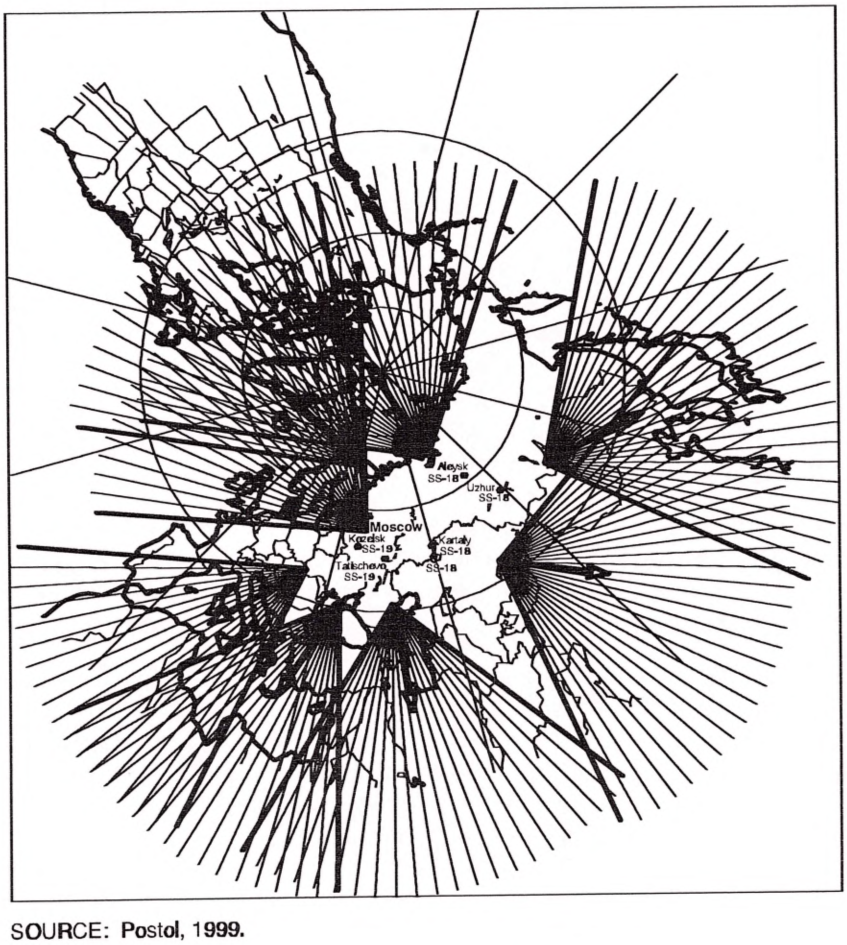
[26]See "The Watchers Fall Asleep in Orbit," *Obshchaya Gazeta*, No. 20, May 2001.

[27]This discussion is based on the analysis in Postol, "The Nuclear Danger from Shortfalls," pp. 19–43, 121–138; Podvig, *Russian Strategic Nuclear Forces*, pp. 420–428; and Forden, *Reducing a Common Danger*, pp. 8–9.

warning radar network with two coverage gaps (see Figure 2.7). These gaps are not as severe as those in the space-based system, but they are nonetheless significant. The loss of the Krasnoyarsk radar has left a wide corridor from the Pacific Ocean all the way to Moscow. Trident missiles launched from submarines based in the Pacific could attack through this corridor without being detected by a missile warning radar or a launch detection satellite. The loss of the



SOURCE: Postol, 1999.

Figure 2.7—Gaps in Russia's Early-Warning Radar System

Skrunda radar created a second, narrower corridor that would permit Trident submarines to attack Moscow from the North Atlantic Ocean without being detected.

The Dangers of an Unreliable System. An unreliable early-warning system is dangerous for two fundamental reasons. First, without a clear, accurate picture of what is happening around the globe, Russia may confuse a benign event (such as a space launch) for a nuclear attack, possibly prompting a decision to launch a nuclear strike. Second, without a properly functioning, two-tiered early-warning system, Russia will have less time available to decide about whether to launch a retaliatory response.

Factor 4: Short Decision Times

Nuclear forces at a high state of readiness create the possibility of a nuclear attack with very little warning. This is particularly true for Russia, since the United States could launch counterforce-capable missiles from Trident submarines based a few thousand miles off Russia's coast and strike targets within 10 to 15 minutes of their initial detection by Russian early-warning systems, provided those systems are functioning. Even ICBMs launched from the United States would give Russia only roughly 25 minutes warning before hitting Russian targets, if Russia could detect their launch. These short warning times mean Russian national and military leaders would have an extremely limited amount of time to decide whether the detected event were a real attack and what course of action to take in response. Decision times are even shorter for Russia today—between 0 and 10 minutes—because of its inadequate early-warning system.

During the Cold War, the nuclear postures of the two sides could support this kind of rapid response because of their large and highly survivable forces and their robust early-warning systems. However, even during the Cold War, the very short time between attack detection (when missiles are first detected) and response (the last response time being just before one's warheads are destroyed by the enemy's incoming missiles) required that the entire nuclear retaliation process be carefully orchestrated and all details worked out well in advance. This meant a large percentage of each side's nuclear forces had to be armed and in position to attack on short notice. For the United States, this kind of planning has been made since 1960 in its

Single Integrated Operational Plan (SIOP). The SIOP specifies which nuclear forces and weapons are to be used to attack specific Russian targets in order to fulfill the U.S. deterrence criteria.

Factor 5: Deterrence Doctrine or Posture Reliant on Launch on Warning or Launch Under Attack

When the perceived vulnerability of Russia's nuclear forces and command and control infrastructure is combined with the short warning times provided by Russia's inadequate early-warning system, another route to accidental nuclear use comes into play: the high probability that Russia has adopted a deterrence doctrine reliant upon launch on tactical warning or launch under attack. In other words, the Russians are most likely posturing their nuclear forces in a way that allows for a quick launch, one that occurs before any U.S. nuclear weapons land on Russian territory or just after the first one arrives. Russia's concern is that its forces will be destroyed by weapons launched from Trident submarines close to its coast if it waits for the arrival of U.S. warheads to verify an actual nuclear attack.

If Russia has adopted a launch-on-warning or launch-under-attack strategy, it needs to posture its forces to execute a retaliatory strike within 10 to 15 minutes after detecting an attack, which is just enough time to launch before the first Trident submarine missiles would strike their targets. Russia could also posture its forces to launch within 25 to 30 minutes, which is roughly the time that would elapse between its satellite early-warning system's initial detection of ICBMs launched from the United States and the impact of the ICBM-borne weapons.

According to one report, the Russians have adopted just such a strategy, one that permits them to launch their strategic missiles within 12 minutes of an attack's first detection by Russia's early-warning system.[28] This kind of rapid response allows very little time to verify that early-warning information is correct. It has also been reported that to counter the risk that its command and control system might be destroyed before it could launch its forces, the Russian leadership

[28]Blair, Feiveson, and von Hippel, "Taking Nuclear Weapons Off Hair-Trigger Alert."

has developed a system, called the "dead hand," that automatically launches a massive counterattack against the United States if Russia is hit by nuclear weapons.[29] At this point, however, there is serious debate about this system's existence.

Factor 6: Inadequate Security and Control of Nuclear Forces and Materials

Russia's current economic conditions have caused much concern about the security and control of Russian nuclear forces in that they could increase the chances of accidental or unauthorized launch. There are two main dangers. The first is that the security around nuclear facilities and forces will be compromised. For example, a local Russian military commander may become so upset about his troops' poor living conditions that, in protest, he takes control of the nuclear forces he commands—i.e., becomes a rogue commander. Another possibility is that there will be a breakdown of security around nuclear forces, weapons areas, storage areas, or development facilities that will allow terrorists to gain control of nuclear materials or weapons. The poor pay and living conditions of Russian nuclear scientists and soldiers may make them susceptible to bribery and other means of persuasion available to terrorist organizations.

The second main danger is that a breakdown of the command and control process will occur. During the Cold War, Russia and the United States had very effective command and control systems. Russia continues to possess a robust battle management system with numerous backup channels and a variety of redundant means for transmitting launch authorization orders to nuclear forces. However, in a crisis with very short decision times, this system could break down.

Factor 7: Inadequate Training Precautions

During a training exercise, an accidental launch could occur either because the exercise itself causes the launch or because the proper

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[29]Bruce G. Blair, statement before the House National Security subcommittee, March 13, 1997; and Blair, *Global Zero Alert*, pp. 51–56.

authorities were not properly alerted of the exercise and thus believe they are under attack. A mistake like this occurred on November 9, 1979, when an exercise tape was accidentally inserted into the U.S. early-warning computer system. Since that incident, measures have been taken to minimize the mistakes that might occur during training. For example, the United States now does its nuclear training in a room other than the one housing the early-warning center.

How the United States and Russia train their forces for nuclear conflict is a highly sensitive topic, and only the most-general details are publicly available. Therefore, while we fully acknowledge that this is an important contributing factor to the possibility of an accidental or unauthorized launch, we are unable to offer concrete solutions to this problem.

CONCLUSIONS

We identified eight basic scenarios for possible accidental or unauthorized nuclear use and grouped them into three types: scenarios leading to unauthorized use, scenarios leading to launch by mistake, and scenarios leading to intentional launch based on incorrect information (see Figure 2.1). Our analysis suggests that seven factors could contribute to accidental or unauthorized use in these three categories.

The next chapter sets forth the criteria we used to evaluate the potential nuclear safety options we arrived at based on our seven contributing factors. This sets the stage for the full evaluations and descriptions of the options in Chapter Four.