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De-Alerting Strategic Ballistic Missiles

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Arms Control Studies Department
Nuclear Weapons Program Integration and Studies Center
Sandia National Laboratories

COOPERATIVE MONITORING CENTER

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Sandia National Laboratories

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De-Alerting Strategic Ballistic Missiles

Abstract

This paper presents a framework for evaluating the technical merits of strategic ballistic missile de-alerting measures, and it uses the framework to evaluate a variety of possible measures for silo-based, land-mobile, and submarine-based missiles. De-alerting measures are defined for the purpose of this paper as reversible actions taken to increase the time or effort required to launch a strategic ballistic missile. The paper does not assess the desirability of pursuing a de-alerting program. Such an assessment is highly context dependent. The paper postulates that if de-alerting is desirable and is used as an arms control mechanism, de-alerting measures should satisfy specific criteria relating to force security, practicality, effectiveness, significant delay, and verifiability. Silo-launched missiles lend themselves most readily to de-alerting verification, because communications necessary for monitoring do not increase the vulnerability of the weapons by a significant amount. Land-mobile missile de-alerting measures would be more challenging to verify, because monitoring measures that disclose the launcher's location would potentially increase their vulnerability. Submarine-launched missile de-alerting measures would be extremely challenging if not impossible to monitor without increasing the submarine's vulnerability.

Acronyms and Definitions

ASW	antisubmarine warfare
CFE	Conventional Forces in Europe treaty
ICBM	intercontinental ballistic missiles
INF	Intermediate-range Nuclear Forces treaty – for intermediate-range ground launched missiles
IRBM	intermediate-range ballistic missile
LAD	launch-assist devices
MOU	Memorandum of Understanding
NATO	North Atlantic Treaty Organization
NPT	Non-Proliferation Treaty
NRRC	Nuclear Risk Reduction Center
OSI	on-site inspection
PAL	permissive action link—a device used to unlock a warhead's arming circuitry
PBV	post-boost vehicle—platform that distributes warheads
SALT	Strategic Arms Limitation Talks
SLBM	submarine-launched ballistic missile
SLCM	sea-launched cruise missile
SSBN	sub-surface ballistic missile nuclear (ballistic missile submarine)
START	Strategic Arms Reduction Treaty
TEL	transporter-erector-launcher—launch platform for mobile missiles
UK	United Kingdom
U.S.	United States
USSR	Union of Soviet Socialist Republics

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De-Alerting Strategic Ballistic Missiles

Executive Summary

This paper presents a framework for evaluating the technical merits of strategic ballistic missile de-alerting measures, and it uses the framework to evaluate a variety of possible measures. The types of missiles considered for de-alerting measure application are found in the United States (U.S.) and Russian arsenals; however, the paper does not evaluate the desirability of a de-alerting program in the U.S-Russian context, or any other specific context. Rather, it examines measures that might be taken if a decision to undertake a de-alerting program has been made. It is important to note that a technical analysis of the measures under consideration would be an important, but not the only, factor in a well-considered decision about the desirability of de-alerting. It is also important to note that context may impact the technical evaluation of de-alerting measures. This paper identifies the contextual factors that should be considered, but does not directly analyze de-alerting measures in their larger context. Because of this, the evaluations presented indicate the general, technical merit of the de-alerting measures considered but do not pass final judgement on them.

De-alerting measures are defined for the purpose of this paper as *reversible actions taken to increase the time or effort required to launch a strategic ballistic missile.* The goal considered for de-alerting is to reduce the risk of accidental, unauthorized, or ill-considered launches, and to allow time for negotiation and reconsideration during crises.

To gain the greatest benefit, de-alerting measures:

- must significantly increase the time and effort required to launch strategic weapons;
- should not decrease deterrent value unless such decrease is compensated by a reduction in the threat by adversaries;
- should not decrease the safety, security, or reliability of strategic weapons;
- should allow a stable return to alert status, if necessary;
- should be practical and effective; and
- should be verifiable.

Silo-launched missiles lend themselves most readily to de-alerting verification, because communications necessary for monitoring do not increase the vulnerability of the weapons by a significant amount, although the de-alerting measures themselves may increase vulnerability. In addition, the silo itself restricts access to the missile inside, which eases the task of monitoring to confirm that removed components have not been replaced. Land-mobile missile de-alerting measures would be more challenging to monitor, because communication measures that may disclose the launcher's location would potentially increase their vulnerability. Submarine-launched missile de-alerting measures would be extremely challenging if not impossible to

monitor without increasing the submarine's vulnerability. Tradeoffs between confidence in the monitoring method and the vulnerability of the force would be necessary.

Tables 6, 7, and 8 summarize our general and qualitative evaluation of the technical merits for several de-alerting measures.

De-Alerting Strategic Ballistic Missiles

1. Introduction

1.1 Purpose

The purpose of this paper is to present a framework for evaluating the technical merits of strategic ballistic missile de-alerting measures and use the framework to evaluate a variety of possible measures for silo-based, land-mobile, and submarine-based missiles. The paper does not evaluate whether de-alerting is desirable in any specific context; rather, it examines measures that can be taken if a decision to de-alert has been made. We start with a definition of de-alerting and its objectives, describe precedents for de-alerting measures, suggest criteria for evaluating de-alerting measures, and finish by discussing and evaluating a range of de-alerting measures and their general features in terms of the suggested criteria.

1.2 Definition of De-Alerting

We define de-alerting as follows:

> ***De-alerting*** *is the use of procedures or reversible physical constraints that increase the time or effort required to launch a strategic ballistic missile.*

De-alerting is reversible and is not weapon elimination. De-alerting is applied to weapons that would be retained and remain a part of a nation's strategic operation plan. The term "deactivation," in contrast to de-alerting, generally designates constraints to be placed on weapons that would be eliminated. While de-alerting and deactivation can use the same measures, their ultimate goals are different. Also, in contrast to de-alerting, deactivation may use measures that are irreversible.

This paper considers selected confidence building measures in addition to de-alerting measures because they complement de-alerting measures. They are not themselves de-alerting measures because they do not fit our definition of de-alerting. The paper also considers selected command and control measures because they may be precursors to de-alerting. One may argue that they are in fact de-alerting measures because they add constraints and procedures that require time and effort; however, the additional time and effort are not great, and the motivation is different. The motivation for command and control measures is to ensure that the proper persons are in control, not to slow down a launch procedure.

1.3 Background

During the late 1940s and 1950s, U.S. nuclear forces were kept at a low alert level. The major strategic weapons (bombs) were kept in storage bunkers. Bombers engaged in training exercises but were not routinely loaded with bombs and were not kept airborne. Hours to days of preparation would have been required to launch a nuclear strike. This state gradually changed in the late 1950s. The growth of strategic forces and the development of intercontinental ballistic missiles (ICBMs) generated a situation where nuclear forces were kept at a high alert status to avert the risk of being destroyed in a sudden, surprise attack. (By "state of high alert," we mean a state in which nuclear weapons can be launched within a few minutes.) By the end of the 1950s, some U.S. bombers were kept on constant alert at the end of runways, fueled, armed, and ready to fly. After the Berlin Crisis in 1961, the U.S. kept a portion of its bomber force on airborne alert. The airborne alert force was in the air at all times, loaded with nuclear weapons. By the early 1960s, the U.S. had thousands of nuclear warheads deployed on ICBMs, submarine-launched ballistic missiles (SLBMs), intermediate-range ballistic missiles (IRBMs), and aircraft at high alert. While the exact alert level of the Union of Soviet Socialist Republics (USSR) forces was unknown, it was believed to be high, as well. Today, both the U.S. and Russia keep ballistic missiles, but not bombers, in a highly alert state.

Concerns in the United Kingdom (UK) about survivability have been the same as those of the U.S. After the deployment of the Soviet ICBM forces, part of the British bomber force was placed on a 15-minute Quick Reaction Alert. This was an on-the-ground alert state similar to that used by U.S. tactical aircraft assigned to the North Atlantic Treaty Organization (NATO). After they acquired SLBM forces, the British policy was to maintain two submarines on patrol at sea at all times. (See Figure 1.) At sea, the submarines maintain a variety of alert states, ranging from being unable to launch for several hours to being able to launch within 15 minutes. Recently, Britain announced that their aircraft-delivered nuclear bombs were retired. This leaves the SLBM force as their sole nuclear force. The number of warheads per submarine is also to be reduced.

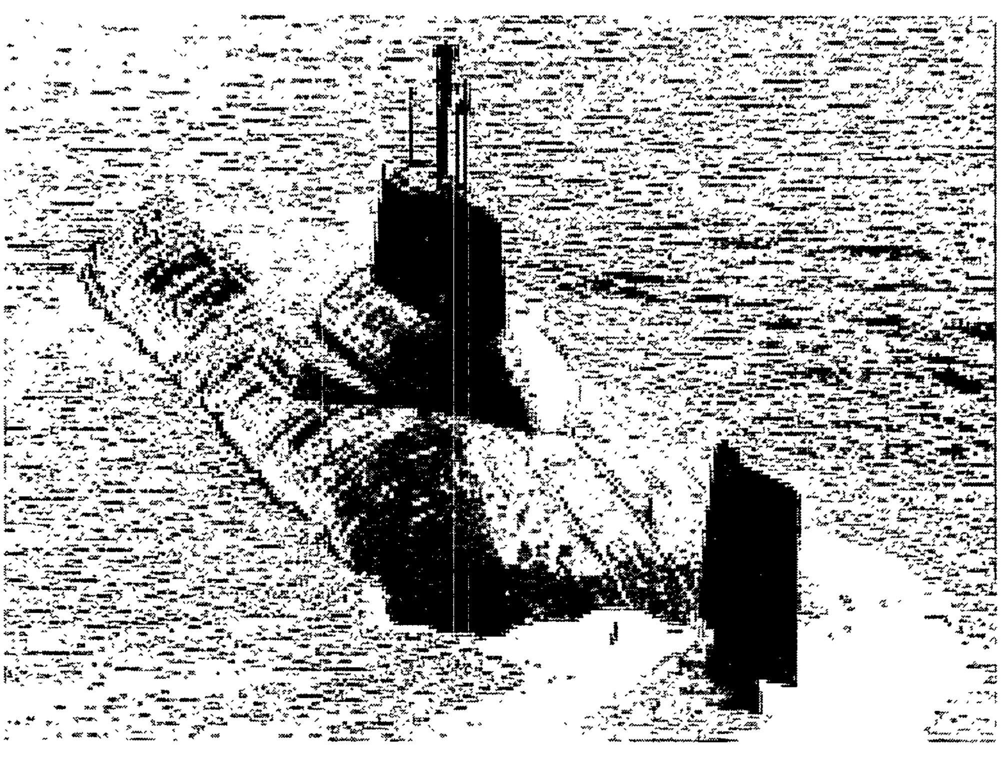

Figure 1. Submarine Capable of Nuclear Missile Launch

Until recently, France had a triad of bombers, land-based missiles, and sea-based missiles. As of the late 1980s, a fraction of the French bomber force was kept on 15-minute ground alert. The land-based missiles were kept at a high alert state, reportedly capable of launch within a few minutes. At least three SSBNs (sub-surface ballistic missile nuclear submarine) were kept at sea at all times. Intermediate-range ballistic missiles and long-range bombers are now retired.

Little information is available on Chinese alert states. It has been speculated that Chinese ICBMs are normally maintained at a relatively low alert status—without their warheads and fuel. If this is true, they believe that they would have time to fuel their missiles and load warheads in a crisis. Likewise, it has been speculated that India and Pakistan have nuclear arsenals maintained in a de-alerted state.

Fear of accidental or unauthorized use of strategic weapons motivated a series of decisions, agreements, and treaties (discussed in the next section) between the U.S. and the USSR. These agreements established measures to reduce the threat of accidental or unauthorized launches and add some transparency to the intentions of the adversaries. This process was started after the 1963 Cuban Missile Crisis, and continued through the 1960s, 1970s, and 1980s. In the late 1980s and 1990s, the process accelerated, helped by the improvement in relations between the U.S. and the USSR and its successor, the Russian Federation. These measures have sought to improve strategic stability by decreasing the risk of accidental or unauthorized launch and by decreasing the possibility that incidents and intentions would be misinterpreted. We believe that de-alerting will continue to be debated between the U.S. and Russia and by other nuclear weapon states as they consider the alert status of their own systems. In addition to the countries mentioned above as states possessing nuclear weapons, a number of countries are believed to possess ballistic missiles or the capability to produce them: Afghanistan, Algeria, Argentina, Azerbaijan, Belarus, Bulgaria, Egypt, Georgia, Iran, Iraq, Israel, Japan, Kazakhstan, Libya, North Korea, Poland, Romania, Saudi Arabia, Serbia, South Korea, Spain, Syria, Taiwan, Ukraine, United Arab Emirates, Vietnam, Yemen, and Zaire.

1.4 De-Alerting Objectives and Features

Proponents of de-alerting argue that de-alerting should foster two primary objectives:

1. the likelihood of accidental or unauthorized use of strategic ballistic missiles is reduced; and

2. time for clarifying information, reconsideration, or negotiation is increased because weapons are not ready for immediate use.

In addition, we suggest that de-alerting should have the following features if it is to be used as an arms control mechanism:

- strategic stability is maintained;

- deterrent value is maintained;

- a stable return to alert status can be made, if necessary;
- safety, security, or reliability of strategic weapons are not decreased;
- measures are practical and effective; and
- clear indications are given to confirm that weapons are de-alerted or warn if they are re-alerted.

De-alerting measures should introduce delay in the use of weapons, and they should do so in a way that preserves a stable state of deterrence and maintains stability if weapons are re-alerted. Return to a heightened alert state must be possible without passing through stages where either party can gain a decisive advantage over its opponent. In addition, the re-alerting processes should be sufficiently transparent that other parties can detect it in time to make a credible response. By transparent, we mean that the relevant actions of one party are apparent to the other parties. Transparency would typically be achieved through communications and through verification activities, including monitoring. While unilateral actions can have a de-alerting effect, arms control benefits can be derived only when the state of readiness for weapons employment is apparent to all parties. For example, transparency might reduce the risk of misinterpreting a potentially provocative action. Transparency could also make surprise attacks more difficult. It is clear that complete transparency would not be a goal for every party. Generally, most countries desire that their actions not be misunderstood; and they desire to correctly interpret their adversary's actions; but they would not desire to share all their actions with an adversary. Transparency measures must balance these desires.

Many analysts believe that for the present U.S.-Russian context, de-alerting can be destabilizing and can have a negative impact on deterrence. Consideration of de-alerting measures for other pairings of states would have to be based on analysis of their specific context. This paper does not assess these larger, contextual strategic stability aspects, nor does it discuss the general desirability of de-alerting. Instead, it concentrates upon assessing how the technical features of several proposed strategic missile de-alerting measures may create time delay and transparency and how they may affect force security.

1.5 The Importance of Strategic Context

This paper does not examine the overall desirability of de-alerting measures. It is important to keep in mind that a full assessment would address not only the technical issues addressed in this paper but also the specific strategic context in which the measures would be implemented. Some measures may be beneficial for a certain geographical region, but destabilizing if applied to another region. The factors that determine what alert status is deemed necessary may vary from region to region and perhaps between countries within the same region.

The first factor is the **perceived threat to a country's strategic forces**. This factor drove the alert status of the U.S. and Russia from the late 1950s to the present. If a preemptive strike has a high probability of destroying a nation's strategic forces, then alert states would probably be kept at a high level, and a launch-on-warning policy could be adopted. This would be done to ensure that, in the event of attack, at least a few weapons could be launched. If the probability of a successful preemptive attack were perceived to be low, then there would be less need to maintain forces at a high alert status. Measures that increase the survivability of strategic forces may make it possible to reduce the alert status. On the other hand, de-alerting measures that decrease force survivability may be destabilizing and unacceptable.

A second factor is the **existing strategic balance**. If one party has many more weapons than the other does, it may feel confident enough to accept a low level of alert. The weaker party may perceive a need to keep all its forces on high alert. Differences in force structure and deployments may also exert an influence. For example the survivability of forces would exert a critical influence. In many cases, all parties would not have a triad of systems (ICBMs, SLBMs, and bombers) as the U.S. and Russia do. For example, one party may have SLBMs and the other may not. It might be difficult to negotiate an equitable de-alerting agreement when asymmetries are great.

A third factor is related to the **purpose of a strategic force**. If the major purpose of the force is to deter or repel a conventional invasion, then a low level of alert may be acceptable. On the other hand, if the purpose of the force is to deter or reply to an attack by nuclear-armed missiles, fast response may be perceived to be essential.

A fourth factor is the **size and location of the countries involved**. Lack of area to disperse their forces may make small countries vulnerable to air or missile attack, special operations forces, or even conventional ground forces. If potential opponents share a common border, these vulnerabilities are exacerbated. This situation can motivate a country to maintain its forces at a high alert level in order to ensure a rapid response. In addition, some potential de-alerting measures, such as moving delivery systems away from deployment areas, are more difficult if countries are in close proximity.

The last factor is **resource constraints**. If numbers of strategic delivery systems are not large, the loss of even a few systems might cripple a strategic force. Any measures that may potentially increase vulnerability might be unacceptable. On the other hand, limited resources make it less likely that a nation can launch a preemptive strike to destroy all the strategic forces of its opponent. Maintaining a high alert status is expensive, so de-alerting may save money. However, the capability to monitor de-alerting agreements may be limited because of budgetary, technical, or political constraints.

While context is critical in determining whether de-alerting is acceptable in an actual situation, this paper does not consider a specific context, nor does it make a judgement on the general acceptability of de-alerting. Instead, it explores some of the technical issues associated with implementing de-alerting measures.

2. De-alerting Measures and Precedents

This section discusses types of de-alerting measures, as well as selected confidence building and command and control measures, and their associated precedents. Nearly all of the precedents discussed here come from agreements, treaties, and unilateral actions by the U.S. and USSR (or Russia) which have large arsenals and relatively sophisticated monitoring capabilities. Many future de-alerting activities may be between countries with small arsenals and limited monitoring capabilities. De-alerting measures must be adapted to the context in which they are used.

De-alerting measures should be amenable to transparency and monitoring to verify that a warhead or delivery system is de-alerted and to detect re-alerting. The discussion of precedents includes some monitoring measures that have been used in the past, but a more thorough discussion of verification is given in a later section of this paper.

We have included selected confidence building and command and control measures in this discussion. Although they are not de-alerting measures, they complement and support de-alerting measures and, in some cases, may be precursors to de-alerting. For this reason they are included in this analysis.

The following measures are addressed in this paper:

1. Communication links between parties
2. Notification agreements for potentially provocative events, such as test launches
3. Administrative and technical launch procedures (use control)
4. Post-launch measures, such as in-flight self-destruct or de-targeting commands
5. Launch barriers that would prevent a successful launch
6. Warhead, key component, or key information removal
7. Delivery system removal from deployment areas or launch sites
8. Warhead or delivery system disassembly

We list the measures in this order because they progress from a "less de-alerted" state to a "more de-alerted" state. We have tried to cover those measures that have been discussed in the open literature, as well as several measures that became apparent in the course of this analysis. These measures will be described in the following sections. Items 1 and 2 are confidence building measures, items 3 and 4 are command and control measures, and items 5 through 8 are de-alerting measures. These measures will be described in the following sections.

2.1 Communication Links

A possible first step in a de-alerting process is to establish fast, reliable communication links between the parties. Communication links are confidence building measures and are not considered to be de-alerting measures. They can help calm tense situations and eliminate misperceptions. The first such agreement between the U.S. and USSR was the Direct Communication Link Memorandum of Understanding (MOU) signed in 1963 (the "Hot Line" Agreement). This agreement established a direct telegraph-teleprinter line with radio backup between the heads of state. The aim was for provocative incidents or situations to be discussed and resolved without a nuclear exchange.

The U.S.–USSR hot line has been used on several crisis occasions. It was used successfully during the 1967 Arab-Israeli war to help resolve a situation where a U.S. communications ship had been accidentally attacked and it was initially unclear who had conducted the attack. It was also used in the 1973 Arab-Israeli War, the 1974 Turkish intervention in Cyprus, and during the 1979-1980 Soviet intervention in Afghanistan.

The 1963 agreement has been augmented by several subsequent agreements. The 1973 U.S.–USSR Agreement on Prevention of Nuclear War mandated consultation in tense situations. The 1984 U.S.–USSR Direct Communication Link MOU expanded communication links for additional security and reliability and added a high-speed facsimile capability to the original communication link. The 1987 U.S.–USSR Nuclear Risk Reduction Center's Agreement added communication centers with FAX capability. The nuclear risk reduction centers (NRRCs) are intended to ensure direct government communication below the level of heads of government. They are used to facilitate the information exchange required under several agreements, including the Strategic Arms Reduction treaties (START).

Communication links can be established in many different ways, including communication through a third party. Direct telephone or electronic links offer the advantage of speed and immediate availability but may not be possible between parties who refuse to speak to each other. In addition, there is the possibility that abusing a communications link to send threats or disinformation may worsen a crisis.

While communications links may not be necessary to initiate de-alerting measures, an agreement to communicate can be an important practical first step for confidence building and establishing a precedent for cooperation that can facilitate later de-alerting measures.

2.2 Notification Agreements

Potential adversaries could agree to notify each other of upcoming events related to strategic weapons that might be mistaken for hostile acts. These are also confidence building rather than de-alerting measures. Notification agreements can reduce the risk of a misinterpreted event precipitating a nuclear exchange and they have confidence building value. The 1971 U.S.–USSR Agreement on Measures to Reduce the Risk of Outbreak of Nuclear War (a part of Strategic Arms Limitation Talks (SALT) I) called for prompt notification of provocative events (such as unauthorized use or unexplained incidents involving a detonation of a nuclear weapon) and ICBM launches. The 1972 Incidents at Sea Agreement and the 1989 Dangerous Military Activities Agreement bind the U.S. and Russia to notify each other of military activities that can be misinterpreted as hostile. The 1977 UK–USSR Prevention of Accidental Nuclear War Agreement requires notification of nuclear-related accidents. An agreement at the 1986 Stockholm Conference on Confidence and Security Building in Europe mandates prior notification of military exercises and for observation of those activities. The 1988 U.S.–USSR Notification of Missile Launch Agreement extended the 1971 agreement to SLBMs. The 1989 U.S.–USSR Agreement on Notification of Strategic Exercises requires prior notification for exercises involving heavy bombers.

The nature of notifications is to prevent a crisis rather than to resolve a crisis. Because they function on a routine basis, it is hard to find information about specific examples of their effectiveness. The steadily increasing number of notification agreements between the U.S. and Russia, however, must be seen as evidence of their perceived value. An example of a notification process that did not work well illustrates that the structure of the notification process is important. In 1995, the launch of a Norwegian sounding rocket caused great alarm in Russia. Although the Norwegians had given notification of the launch, the notification had not reached the organizations responsible for early warning, nor had it reached the Russian president. The notification must not only travel from one party to another, but it must reach the proper authorities within the parties.

2.3 Administrative and Technical Launch Procedures

A variety of administrative and technical procedures can be used to prevent an accidental or unauthorized launch. These are considered to be command and control rather than de-alerting measures, as follows:

- Requiring launch personnel to use a special key or code for accessing, arming, or launching a weapon system. (The U.S. Permissive Action Links (PALs) are an example.)

- Requiring the simultaneous insertion of two or more keys or codes by two or more launch personnel.

- Removing keys or codes from launch personnel and putting them in the possession of a higher authority.

- Placing control of keys or codes in the hands of an organization different from the one responsible for weapons launch.

These measures offer varying degrees of protection against accidental or unauthorized use. All five add some time, probably a few seconds to a few minutes, to a launch procedure. A significant amount of time may expire, however, in transmitting the keys or codes to the launch crew.

There are several precedents for agreements to use these types of measures. The 1971 U.S.-USSR Agreement on Measures to Reduce the Risk of Outbreak of Nuclear War and the 1977 UK-USSR Prevention of Accidental Nuclear War Agreement mandate organizational and technical safeguards to prevent accidental or unauthorized use of nuclear weapons. We do not know of any monitoring measures that have been used with these administrative and technical procedures.

2.4 Post-Launch Measures

Post-launch measures would prevent a missile from reaching a target after being launched. These are also considered to be command and control rather than de-alerting measures. Examples are self-destruct commands or guidance commands that would change its impact point. There are no precedents for using these measures on operational missiles, but self-destruct commands have been used for safety purposes on U.S. missile test ranges since the beginning of the U.S. missile program.

2.5 Launch Barriers

A variety of electronic or physical barriers can significantly increase the time for a launch procedure, as follows:

- Introducing a timer into the launch system that produces a specified launch sequence time delay, during which time the launch can be canceled;
- Covering launch silos with dirt or a heavy object;
- Welding silo doors closed or disabling the door-opening mechanism;
- Adding a device to a transporter-erector-launcher (TEL) or submarine that makes the launch mechanism inoperable until the device is removed; or
- Attaching devices to the missile that prevent flight.

We do not know of any precedents for these measures or for associated monitoring methods.

2.6 Warhead, Key Component, or Key Information Removal

Detaching or removing warheads, key components, or necessary information from delivery systems can add a significant time delay to a launch procedure. The delay can be several minutes for bombs delivered by aircraft to several hours for warheads delivered by missiles.

The following measures would add time to a launch procedure:

- Inserting "harmless" target coordinates into a weapon system's navigational system so that the real coordinates must be reentered prior to launch (this is known as de-targeting and may be considered by some to be a confidence building measure instead of a de-alerting measure);
- Removing umbilicals or other wiring essential for the firing order to reach a missile;
- Detaching warheads from missiles;
- Discharging missile or launcher batteries so that they must be recharged before launch;
- De-fueling liquid fueled missiles or aircraft so that they must be refueled before launch;

- Physically removing critical missile components, such as computers, guidance packages, batteries, or igniters.

In 1994, the U.S. and Russia agreed to de-target their missiles "aimed" at each other by removing the target coordinates from their missile guidance systems. In May 1997, President Yeltsin stated that Russian missiles would no longer be targeted at NATO states, and in June 1997 he extended the statement to Japan and China.

There are some precedents for detaching warheads and key components from delivery systems. In the 1950s, U.S. bombs were always stored away from aircraft. The earliest U.S. nuclear weapons (bombs) were designed so that the fissile material was kept separate from the rest of the weapon as a safety measure. The complete weapon was assembled during flight. It has been reported that the first Russian ICBMs were deployed without warheads and were only assembled in times of crisis. It is speculated that Chinese missiles are deployed without fuel or warheads. In the 1994 U.S.-Russian-Ukrainian Trilateral Agreement, Ukraine agreed to detach warheads from its missiles until they can be transferred to Russia. At the Helsinki Summit in 1997, Presidents Clinton and Yeltsin proposed that missiles that would be eliminated under START-II be "deactivated" by removing their warheads, or taking other jointly agreed-on steps, while they are awaiting elimination. On May 27, 1997, President Yeltsin announced that warheads would be removed from missiles aimed at Europe. The statement was retracted with the claim that he misspoke and that what he meant to say was that missiles aimed at Europe would be de-targeted. Yeltsin's statement opened the issue of removing warheads from missiles even though it was a misstatement.

If the removed components were stored at a considerable distance from the missile, this would add significant time to a launch. There is a precedent for keeping warheads outside a potential deployment area. One provision of START I prohibits storage of nuclear weapons within 100 km of a conventional bomber base. This provision allows for verification by on-site inspection (OSI) and is intended to inhibit rapid re-conversion of conventional bombers to nuclear delivery systems.

Central storage of removed components may facilitate monitoring (at the risk of increasing vulnerability) by allowing components to be concentrated in a monitored facility instead of scattered over launch sites. It probably would not be possible to restrict access to components such as warheads by the country that owns them, but it may be possible to establish transparency by keeping them in monitored areas. The monitoring system can give notification when a country withdraws warheads or other components from the monitored area. No precedent for cooperatively monitoring strategic weapon storage areas exists. However, there is substantial precedent for highly intrusive monitoring of nuclear facilities under the Non-Proliferation Treaty (NPT).

2.7 Delivery System Removal from Deployment Areas or Launch Sites

Removing complete delivery systems from deployment areas or launch sites adds significant time to a launch procedure. There are several precedents for this type of measure. Historically, the U.S. has not stationed its main force of heavy bombers with nuclear weapons in foreign countries except during a crisis. In 1967 the U.S. unilaterally removed strategic bombers with nuclear weapons from airborne alert. In this case, the sky might be considered a launch site. Nuclear-free zones exclude delivery systems from potential launch sites. In 1991, Presidents Gorbachev and Bush made "unilateral" decisions to remove short-range nuclear weapons from Europe, a potential launch area. At roughly the same time, the U.S. unilaterally withdrew nuclear weapons from South Korea. In 1993, the U.S. made a unilateral decision to remove all nuclear weapons from surface ships and to remove sea-launched nuclear cruise missiles (SLCMs) from submarines.

A precedent for monitoring weapon systems removed from deployment areas to confirm their removal was established by the Conventional Forces in Europe (CFE) treaty, which mandates inspection of conventional weapon storage areas.

2.8 Warhead or Delivery System Disassembly

Disassembling warheads or delivery systems would generate the greatest delay of all the measures discussed in this paper. Disassembly falls short of elimination but provides a greater degree of delay in a launch procedure than any other de-alerting procedure.

Disassembly is usually a step in a weapon elimination process; however, there are precedents for maintaining delivery systems for long periods in a disassembled state. As stated before, early U.S. bombs were stored in a disassembled state. East Germany, Slovakia, the Czech Republic, and Bulgaria destroyed the connecting sections of SS-23s in their possession before the Intermediate-range Nuclear Forces (INF) treaty was signed. These countries kept the disassembled missiles through 1994.

3. De-Alerting Measure Evaluation

3.1 Criteria for Evaluating De-alerting Measures

De-alerting measures have positive and negative aspects. We suggest that five criteria be used to identify and evaluate those de-alerting measures that are most suitable for a given strategic situation, as follows:

1. Force security
2. Practicality
3. Effectiveness
4. Delay
5. Verifiability

Force security is 1) the effect that the de-alerting measure would have on the vulnerability, reliability, or safety of the affected ballistic missile force and 2) the possibility of disclosure of sensitive design or operational information. A measure that makes a force vulnerable to a preemptive strike would not be acceptable to the weapon owner because it imperils the state's deterrent capability and its security. Such a measure may be viewed as destabilizing. Measures to decrease missile force vulnerability may be necessary companions to de-alerting measures. Mutual de-alerting, which would ensure that no party has the capability of mounting a successful preemptive attack, is probably necessary for de-alerting measures to be acceptable. A measure that reveals too much information about a state's strategic force may also be seen as a threat to national security. Stability would also depend on balance. If two parties have very different force structures (for example, one party has land-mobile ballistic missiles and the other has submarine-launched ballistic missiles), de-alerting measures and monitoring may be difficult to apply in a balanced or equitable manner.

Practicality is determined by the cost, manpower, equipment, and facilities needed to implement the de-alerting option. If a measure becomes too costly, it would not be used.

Effectiveness addresses the question of whether or not the measure would really succeed in reducing alert status or whether it could be circumvented easily. Some proposed measures may not delay a successful launch and missile flight even if implemented.

Delay is significant time delay offered by the measure. A delay of a few seconds to minutes may not offer much benefit. On the other hand, a time delay of many months may decrease stability by offering opportunities to interfere with re-alerting.

Verifiability is the ability to confirm initial de-alerting and to detect re-alerting. For example, if a critical component was removed, then an inspector must be able to confirm that the component has, in fact, been removed and that no redundant components were present. Monitoring options can be used to confirm that the de-alerting measure has not been reversed. In our judgement, monitoring is essential to provide transparency and stability to de-alerting if it is used as an arms control measure.

In this paper, we evaluate issues associated with each de-alerting measure, and we make very general qualitative judgments as to which de-alerting measures are the best candidates; however, specific evaluation of de-alerting measures would require careful consideration of the specific context within which the de-alerting measures are to be applied.

3.2 Silo-Launched, Land-Mobile, and Submarine-Launched Ballistic Missiles

The following section evaluates de-alerting measures to which cooperative monitoring technologies can be applied. We consider three classes of missiles: 1) silo-launched ballistic missiles, 2) land-mobile ballistic missiles, and, 3) submarine-launched ballistic missiles. Examples of silo-launched ballistic missiles are the U.S. Minuteman III and the Russian SS-19, both of which would remain operational after implementation of START-II. Examples of mobile missiles are the Russian SS-25 and SS-27, Chinese CSS-2, and Scud-B. Examples of submarine-launched missiles are the U.S. and British Trident, Russian SS-N-23, and French M-45. Issues relating to the evaluation criteria, including potential monitoring options, are discussed for each de-alerting measure.

The original objective for basing missiles in silos was to reduce missile vulnerability to a preemptive strike. (See Figure 2.) In the present U.S.-Russian situation, increased missile accuracy has reduced the survivability of silo-based missiles and increased pressures for both sides to move to an alert state that permits launch on warning. On the other hand, silos prevent the destruction of more than one missile by a single warhead, and provisions in START II would eliminate multiple warheads on ICBMs. These factors would reduce the capability of either side to destroy multiple ICBM warheads with a single attacking warhead. Since one or more attacking warheads may be required to destroy a single warhead, silos containing single warhead missiles may become less attractive targets, and the motivation for a launch-on-warning policy may be reduced. If the motivation for launch-on-warning is sufficiently low, a high alert state may no longer be required, and de-alerting may be acceptable. Since the location of missile silos is generally known, verification methods associated with de-alerting may be acceptable even if they disclose silo location.

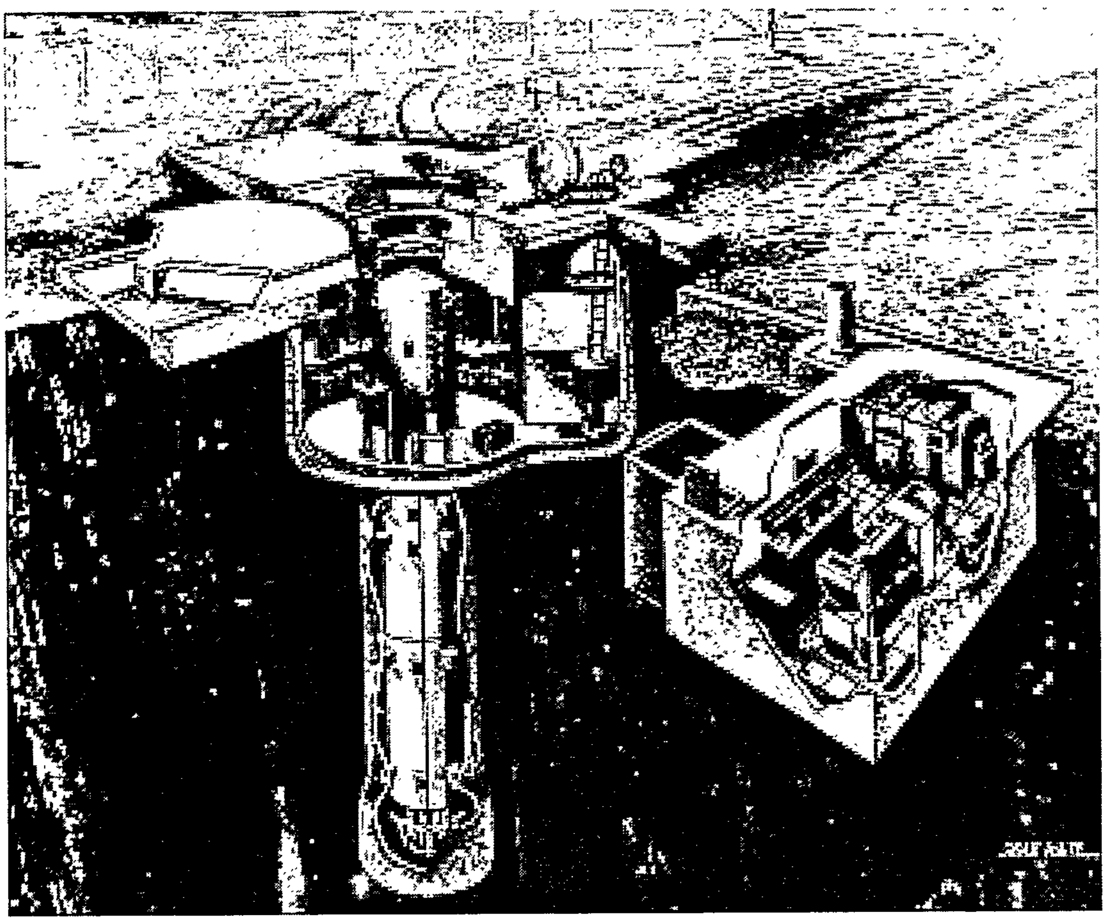

Figure 2. Silo-Based Missile

Unlike silo-launched missiles, which depend on hardened silos to reduce vulnerability, land-mobile missiles depend on location uncertainty for survivability. Land-mobile missiles do not have to launch quickly to avoid destruction in the event of a nuclear exchange, as long as their location is not compromised. Therefore, a time delay caused by de-alerting measures may not significantly increase vulnerability. Also, if START-II were implemented, land-mobile missiles would carry a single warhead and may not be an attractive target because one or more attacking warheads would be required to destroy a single warhead. On the other hand, if the location of the launcher is compromised, it becomes vulnerable, not only to nuclear attack, but also to attacks by conventional forces. (See Figure 3.) Monitoring de-alerting measures without compromising the locations of a land-mobile missile force would be a significant challenge.

Like land-mobile missiles, submarines depend on location uncertainty to reduce vulnerability, but survivability for a submarine is even more important because of the number of missiles and warheads each carries. One submarine constitutes a much larger fraction of a country's strategic force than an individual TEL or silo. Communication associated with monitoring measures would be a significant vulnerability issue if it betrayed the submarine's location. The feasibility of monitoring submarine missile de-alerting may depend on developing monitoring measures that do not divulge the submarine's location.

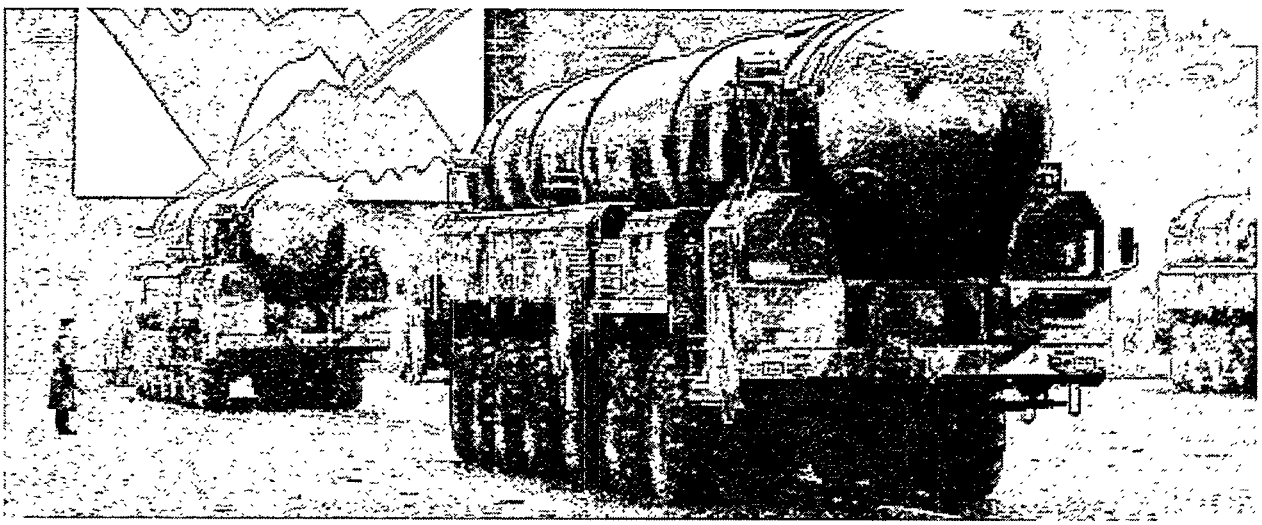

Figure 3. SS-25, Russia's Land-Mobile Missile

3.3 Communication Links and Notification Agreements

Communication links and notification agreements can be an important complement to de-alerting. They are confidence building measures, not de-alerting measures, and we have not evaluated them using the suggested de-alerting criteria.

3.4 Administrative and Technical Launch Procedures

We classify administrative and technical launch procedures (use control) as command and control measures, not de-alerting measures; however, they are complementary to de-alerting measures and are discussed in limited detail below. These can be applied to all three types of missiles, and have value in reducing the risk of accidental or unauthorized launches. Both the U.S. and Russia practice extensive use control measures, but they are not monitored. If these measures can be cooperatively monitored, integrated devices that give an alarm or terminate a "safe" signal when a launch procedure is initiated would be required. In order for this type of monitoring to be accepted, the missile owner must have confidence that the monitoring device cannot interfere with his weapon, and the other party must have confidence that the monitoring device would function properly. These requirements may be very difficult to achieve.

3.5 Post-Launch Measures

Post-launch measures are not de-alerting measures but may be considered as command and control measures. Post-launch measures deal with destroying or diverting a missile after launch. According to available information, most (if not all) currently deployed long-range missiles are designed to be autonomous once launched because of vulnerability concerns. Adding post-launch measures would allow a missile launch to be reconsidered. Self-destruct commands, like those implemented in missiles during testing, could be used. Alternately, the missile might be diverted to an ocean or an uninhabited area if a command was received during boost phase.

Monitoring would require missile inspections to ensure that necessary equipment has been installed in missiles. Destruct signal communication channels can be monitored and tested. Finally, early warning systems may be able to verify that a missile is destroyed or diverted during flight.

It can be argued that post-launch measures might have the opposite effect of de-alerting. Missile owners may be more ready to launch missiles on the basis of ambiguous or conflicting information since they would have the option to destroy or divert the missiles later. This can make accidental or ill-advised launches more likely.

Table 1 lists the command and control measures introduced above and discusses issues that pertain to each of the five evaluation criteria.

Table 1. Discussion of Administrative and Technical Launch Procedures and Post-Launch Measures

Measure	Force Security	Practicality	Effectiveness	Delay	Verifiability
Administrative and technical launch procedures	Use control would enhance security and safety. Monitoring devices may provide a means for disabling a missile or for attacking a strategic command and control system.	Use controls entail increased costs. These costs vary from small for key procedures, to somewhat greater for permissive action links.	Use control should be effective against accidental or unauthorized launches and may have some effect upon ill-advised launches.	Use control can produce seconds to minutes of delay for authorized use and may prevent unauthorized use.	Verifying use controls would require very intrusive OSIs. Technical monitoring devices would have to be installed in very sensitive locations.
Post-launch measures	Divert/destruct signals must be secure from compromise to preserve force security.	These measures require divert/self-destruct mechanisms in the missile and a means of transmitting a signal to the missile, which are added expenses.	It can be effective at terminating a launch, but must be very reliable. Warheads and or fissile material may be released.	This measure would not delay launch at all. The time for action would be a few minutes or less, depending on range. It may have the opposite of the desired effect by encouraging hasty launches and thus be destabilizing.	Intrusive OSIs would be needed to confirm installation of post-launch divert or destruct mechanisms. There is no way to verify with confidence that the other party would actually use post-launch measures.

3.6 Launch Barriers

Launch barrier measures considered for **silo-launched missiles** include

- piling dirt or gravel over silo doors,
- placing heavy weights over silo doors,
- welding silo doors closed,
- removing or disabling the silo door opening mechanism, and
- attaching weights, speed brakes, or other impediments to the missiles.

The launch barriers considered for **land-mobile missiles** include

- launch-obstructing devices and
- alterations to the launcher.

The launch barriers considered for **SLBMs** include

- launch-obstruction devices,
- welding missile ports closed, and
- disabling launch-assist devices (LADs).

In addition, delay timers could be considered as launch barriers for all three platforms.

If unattended monitoring were used, periodic communications from on-site technical monitoring devices confirming correct operation and the absence of tampering (called "state-of-health" messages) would be necessary. The time between communications should be sufficiently less than the time needed to disable the monitoring device and re-alert the missile so that action could be taken to respond to any such re-alerting.

A **delay timer** (see Figure 4) may add a fixed, agreed-upon time delay between the launch signal and launch, which would allow parties to communicate, negotiate, or prepare for their own defense. Monitoring the timer to give an alarm or terminate a "safe" signal when the launch signal is given or if the timer is tampered with or bypassed may be required. If the delay timer were bypassed, delay time may be eliminated even if an alarm was sounded when the timer was bypassed. A delay timer and its monitoring device may be easy to bypass unless it is integrated into the missile or warhead design. Integration of the timer into the missile design would be very intrusive, may be a security issue, and would require that both parties have confidence that the device would perform as expected.

3.6.1 Silo-Launched Missiles

Dirt or gravel piles or a large concrete block over the silo door could prevent missile firing until the mass was removed. (See Figure 4.) Heavy equipment may be required to remove the obstruction. The presence of the large masses may be monitored using imagery from aircraft or satellites (either commercial or national technical means (NTM)) or unattended monitoring devices including video surveillance or motion sensors. If aircraft or satellite imaging were used to monitor door obstructions, the revisit time must be less than the time required to remove the obstructions from a significant portion of the force. It may be sufficient to image random silos in order to deter re-alerting attempts; however, satellite orbits are not random. **Welding silo doors closed** may also offer significant delay because of the time required for cutting welds. Welds may be more difficult to remove than large masses, but they are probably not as easy to monitor. Unattended, remote monitoring may be practical using video surveillance, temperature sensors, or vibration sensors. Assuring the weld quality would require an initial inspection.

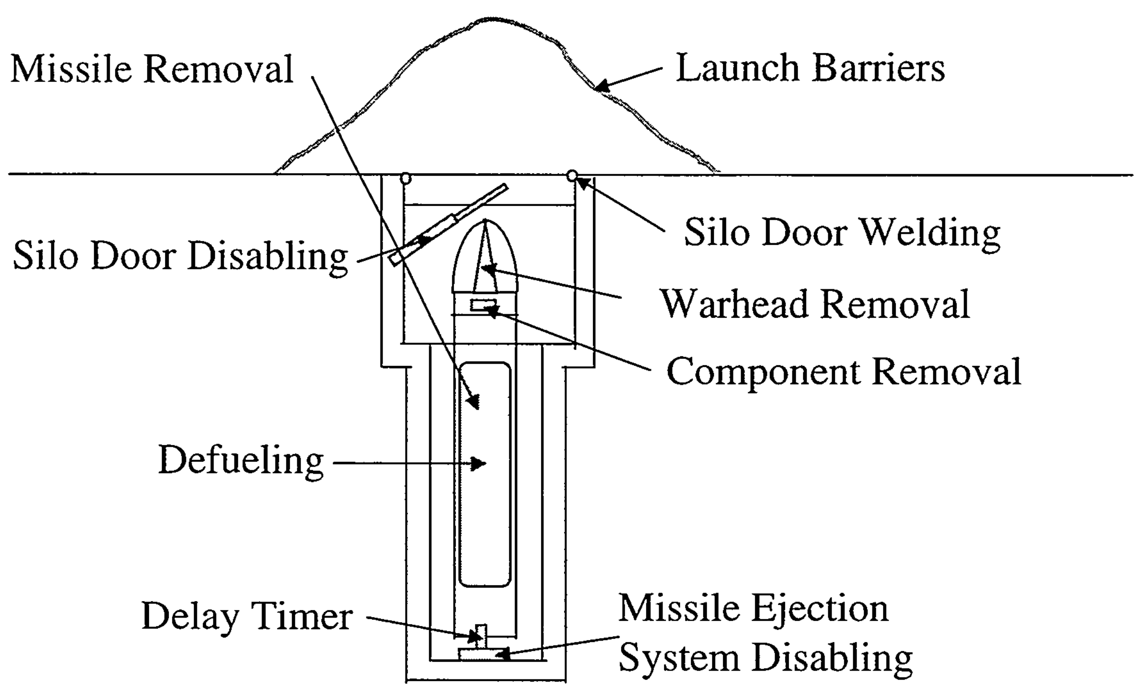

Figure 4. Launch Barriers for Silo-Based Missiles

Removing or disabling the mechanisms used to open the silo doors may impact maintenance procedures less than gravel piles or welding. Tradeoffs could be made between the time delay gained by removing a particular component of the opening mechanism and the difficulty of removing and reinserting that component. Monitoring systems would have to detect the reinsertion of the components. Triggered cameras or movement sensors are possible candidates for unattended, remote monitoring.

Impediments may be attached to a silo-based missile to prevent a successful launch. (See Figure 4.) Examples of such impediments are rocket nozzle plugs and collars that add weight or aerodynamic drag.

3.6.2 Land-Mobile Missiles

A mobile-missile, **launch-obstructing device** may be bolted or welded to the launcher and must be removed before launch. (See Figure 5.) As an alternative, weights or drag-inducing devices might be attached to the missile itself. The device may be monitored using beam interruption sensors or relative motion sensors that would sound an alarm or interrupt a "safe" signal if the obstruction were removed. They may also be monitored by periodic random inspection.

A mobile-missile launcher may be de-alerted by **removing equipment used to raise the missile.** (See Figure 5.) Replacing the equipment may require several days per launcher. The removal could be verified by inspection. Subsequent monitoring could be performed by periodic random inspections or by seals (including magnetic or fiber-optic seals) inserted to replace the removed components.

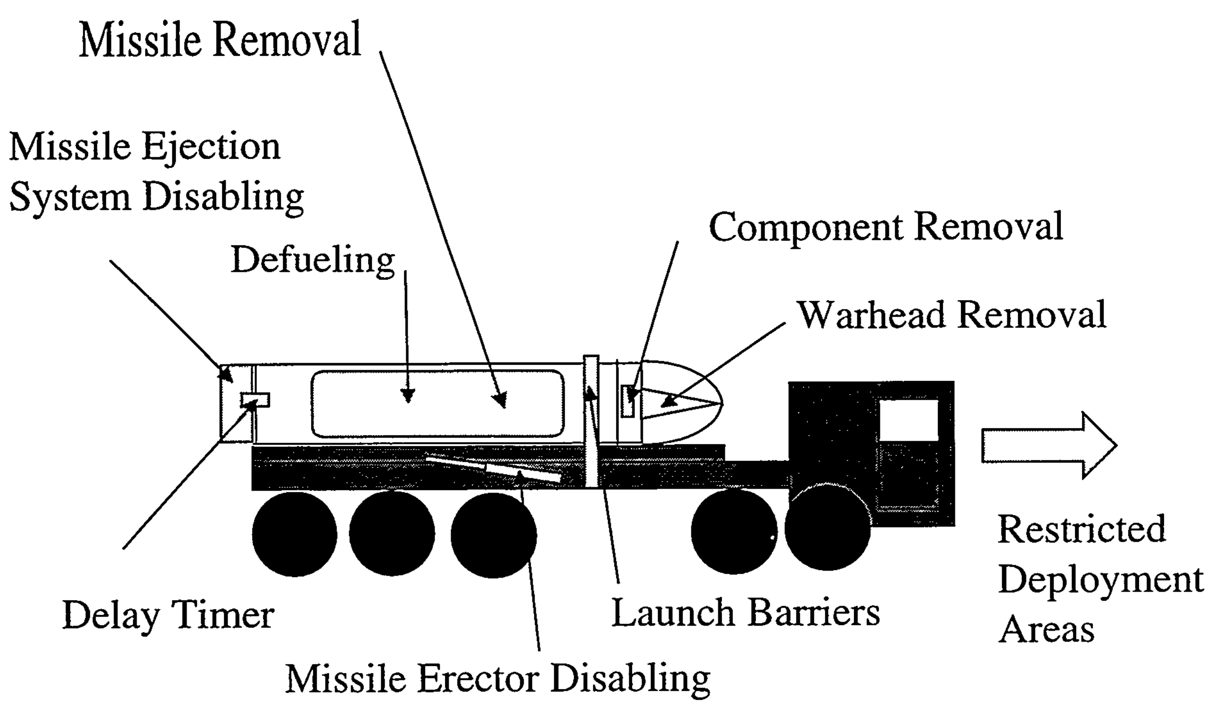

Figure 5. Launch Barriers for Land-Based Missiles

As indicated earlier in this section, survivability of mobile launchers depends upon their location being unknown. Communication for monitoring measures may be a significant vulnerability issue if it betrays the location of the TEL. This concern may be ameliorated if the time between communications were relatively large. Communication times could be staggered so that even if the TEL location were revealed, the location of only a few TELs would be disclosed at any given time, and the vulnerability of the force as a whole would not increase greatly. On the other hand, if de-alerting added only a small amount of time to the launch process, communication with the monitoring devices would have to be frequent, and communications methods that would not reveal location would be necessary. It may be possible for de-alerting signals to be frequently or continuously transmitted without disclosing the missile's location. A communication device may be able to use a restricted field of transmission that would be received by a single satellite only. However, if only one satellite receives the signal, triangulation on the transmitter may be very inaccurate or not possible. This may require an antenna that could be aimed at a single satellite. It may also be possible to send short-range, encoded signals to a network of signal relays that pass on the signal without locating the signal's source. Monitoring options for land-mobile missiles may depend on the practicality of these communication methods that have not been proven in practice.

It may be possible to keep de-alerted land-mobile missiles in garages, similar to present Russian policy. If alerted to an impending strike, which would require reliable warning of an impending strike, TELs could quickly leave the garage. Data transmission from the garages may not be a vulnerability issue if the locations of the garages are already known. If the missile TEL were to leave the garage, then it could be considered to be in an alert state.

3.6.3 Submarine-Launched Missiles

To de-alert submarine-launched ballistic missiles, a **launch-obstructing device** may be bolted or welded to the launch tube's hatch or the hatch itself may be welded, requiring removal of the obstruction before launch. (See Figure 6.) Such obstructions could be inspected before the submarine left port to ensure that they are in place and have integrity. **Welded hatches or obstructions** may offer significant delay because of the time required to remove them. Since it may be possible to remove obstructions or cut welds without surfacing or returning to port, monitoring devices such as active encoded seals or motion sensors may be needed. Welds would have to be cut and obstructions removed before opening hatches to service missiles.

Monitoring sensors that confirm that launch barriers are in place can send periodic state-of-health messages that are received by buoys or satellites, then retransmitted to reduce the possibility of submarine location. However, submerged operation limits the means of transmission. A submarine can periodically come to a shallow depth to extend an antenna above the water, but this may compromise the submarine's location. Alternative communications means include very low frequency radio or sonar. The feasibility of very low frequency transmissions from a submarine at a normal patrol depth would have to be established. Sonar transmissions may be intercepted and compromise the submarine's location. It may be possible for the submarine to communicate through buoys that send a delayed message or through a buoy that it tows at such a distance that the submarine's location cannot be accurately found. These communication methods would require signal authentication and the transmitter would have to be an integral part of the submarine so that it can not be transferred. None of these concepts have been proven.

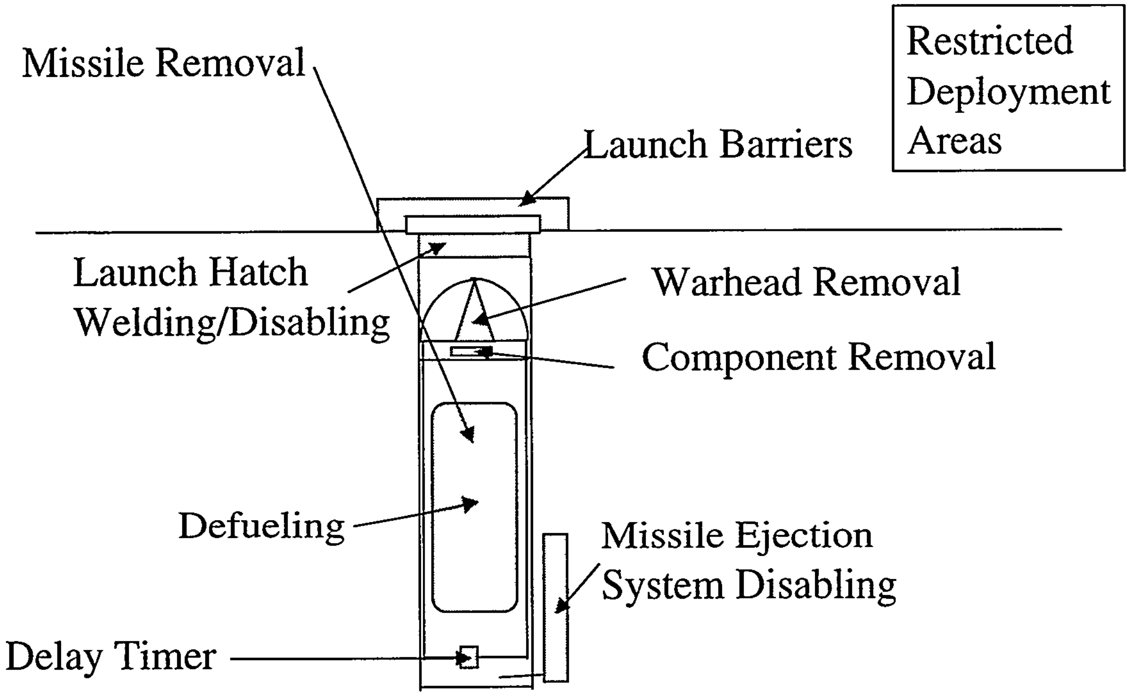

Figure 6. Launch Barriers for Submarine-Based Missiles

Disabling LADs that eject the missile from the launch tube before rocket motor ignition may also be used as a launch barrier. Missiles cannot be launched without the launch-assist device because rocket motor ignition in the launch tube would heavily damage the submarine; however, it may be relatively easy to enable a disabled launch assist device unless the device has been removed (see the next section for removed components). Monitoring to confirm that the device remains disabled would be a challenge.

Table 2 summarizes launch barrier issues for silo-based, land-mobile, and submarine-launched ballistic missiles.

Table 2. Discussion of Launch Barriers

Measure	Force Security	Practicality	Effectiveness	Delay	Verifiability
Delay timers	Integrating the timers into the missiles may reveal sensitive design information and is a potential source of sabotage. Monitoring communications that reveal location would increase the vulnerability of mobile launchers and submarines.	Timer installation would require space aboard the missile and possibly missile design changes.	The timer must be integrated into the missile to prevent bypass.	An agreed-upon time delay can be programmed into the timer. If the timer is bypassed, the delay time may be eliminated.	This measure would require intrusive OSIs to confirm installation. Monitoring devices are necessary to detect tampering and bypass attempts.
Dirt and gravel piles, door weights, door welding for silo-based missiles	Ground crews and equipment may be needed to remove obstructions. These crews are soft targets and are vulnerable during the removal process.	Obstructions must be removed for normal maintenance. Repeated welding and cutting may damage the door.	Quick removal of piles or weights by explosives may be possible. Weights must be heavy enough and welds strong enough to prevent the door from opening.	Obstructions can be made large enough to take several hours to remove by regular machinery, but if rapid removal by explosives is possible, the delay time may be very short. It may take hours to cut through welds. It may be possible to remove welds faster if damage to the door is accepted.	Aircraft/satellite monitoring can detect large obstructions, as can relatively nonintrusive OSIs. Monitoring devices or video surveillance can detect removal efforts. OSIs or technical monitoring would be needed to confirm weld integrity.
Silo door mechanism disabling	If ground crews must go outside the silo to enable the door mechanism, they are potentially vulnerable.	Normal maintenance needs must be considered. There would be a cost associated with restoring the door mechanism.	Cranes, other equipment, or explosive charges might be used to move the door relatively quickly.	Restoring the door mechanism may take hours, but an outside crane or explosive charges might open the door much more quickly.	It would require an OSI to confirm disabling. Aircraft/satellite monitoring can detect cranes positioned near the silos. However, truck-mounted cranes can be brought in a few minutes. If disabled components were inside the silo, monitoring would be more intrusive.

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Table 2. Discussion of Launch Barriers, continued

Measure	Force Security	Practicality	Effectiveness	Delay	Verifiability
Mobile-missile launch obstacles and flight impediments	Force vulnerability would increase if the launch obstacles reduce TEL mobility or if monitoring reveals TEL location.	An obstruction robust enough to prevent missile erection or launch might not fit on the TEL.	Obstructions can prevent launch provided they are not easily removed.	The delay would depend on the time required to remove the obstacle. A few minutes to a few hours are most probable.	An OSI can confirm installation. The obstacle would need a monitoring device or periodic inspections to detect removal.
Submarine launch-tube door obstructions	If the sub must return to port to re-alert, the ports and in-port subs are vulnerable to attack. The obstruction might increase the detecta-bility of the submarine. Monitoring may disclose sub location.	May require hull modifications. If detachable buoys are used to com-municate monitor-ing information, an onboard supply is needed.	Obstructions can be very effective when in place, but obstructions may be easy to remove even at sea.	If they can be removed at sea, the obstructions would take minutes to hours to remove. If they must be removed in port, hours to days would be added to re-alert time.	Installation of launch barriers can be verified by inspection before leaving port. If they can be removed at sea, the obstructions would need monitoring with state-of-health messages transmitted periodically.
Submarine launch-tube door welding	If the sub must return to port to re-alert, the ports and in-port subs are vulnerable.	Welds must be re-moved for maintenance. Repeated welding and cutting may damage the hull.	This measure can be very effective but it may be possible to cuts the welds at sea.	It may require hours to days to cut through the welds on all the tubes.	The initial welding can be confirmed by an OSI, but subsequent monitoring would be very challenging.
Silo-based missile weights or speed brakes	These devices would increase vulnerability if the silo must be opened to remove them. Monitoring devices inside the silo may be a security issue.	There may not be room in the silos or inside missile canisters to mount such devices.	These devices must increase weight and/or drag enough to make successful missile employment impossible.	The time delay would depend upon the time required to remove it. It may be possible that such devices can be removed immediately before or after launch by explosive charges.	An OSI would be needed to confirm installation. Technical monitoring devices inside the silo would be needed to detect attempts to remove the impediments.

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Table 2. Discussion of Launch Barriers, continued

Measure	Force Security	Practicality	Effectiveness	Delay	Verifiability
Mobile missile erector disabling	Erector disabling would compromise force security if it interfered with mobility or if monitoring revealed TEL location.	Removed components can be stored in mobile units or in dispersed storage sites, adding some expense.	Alternative means of raising the missile, such as manual cranks or separate cranes, may be possible.	The delay would depend upon erector design. A few minutes to a few hours are most probable, unless the missile can be raised by other means.	An OSI can confirm disabling. Monitoring devices on the TEL would be needed to detect component replacement.
Submarine launch-assist device disabling	If the sub must return to port to re-alert, the ports and in-port subs would be vulnerable. Monitoring may disclose sub location.	This measure would have relatively low cost.	Very effective unless a redundant method of ejecting the missile from the launch tube was available.	Minutes to hours can be needed to re-enable the device, depending upon the design.	The initial disabling can be confirmed by an OSI, but subsequent monitoring would be very challenging.

3.7 Warhead or Key Component Removal

Key components include missile fuel (if liquid fueled), warheads, igniters, inertial platforms, navigation computers, batteries, post-boost vehicle (PBV) fuel, PBVs, and warhead section shrouds. A related category is essential information in the guidance system (de-targeting).

De-fueling would produce significant time delay for a liquid fueled missile. Refueling a large missile requires hours and refueling an entire force would require much more time. The large quantity of liquid makes several verification and monitoring options available. Observers during the de-fueling process can confirm that the fuel hoses were attached to the missile. They can then confirm that a sufficient weight of fuel had left the missile to make it unusable. The means to do this would vary, depending upon the situation. If the fuel was being pumped into trucks, pre- and post-process weighing of the trucks can measure the amount of fuel removed. It might be possible to burn the fuel. If that happened, the size and duration of the flare would give an indication of the fuel amount. Flow meters can be installed on the trucks. It may even be possible to produce a rough measure of the change in missile weight without removing the missile from the silo by using strain gages that detect changes in missile weight. Once de-fueling has occurred, refueling can be detected by monitoring the silo door, for silo-based missiles, or using strain gages. The de-fueling measure might require fuel storage. If liquid-fueled submarine launched missiles must return to port for missile refueling, delay time would be increased; however, refueling missiles at sea may be possible, in which case monitoring would be difficult.

Detaching warheads or PBVs with warheads can offer significant delay (roughly an hour for a single warhead missile and up to several hours for each multi-warhead missile) because of the time required to reattach them. If submarine warheads are detached and left in port, then submarine travel time must be added to the delay. Warhead or PBV removal involves several activities that would be very noticeable for silo-based missiles and submarines, which reload in port. The large silo door must be opened for silo-based missiles. A crane or other lifting device must be positioned over the missile and the warheads lifted out. The warheads must be transported to a secure storage site. All these activities take several hours and would involve several vehicles. Inspectors can confirm the warhead removal. Most missiles are designed in such a way that the gap left by a removed warhead is apparent provided the shroud is removed. The warheads themselves can be covered so that weapon design information gained by the inspectors might be minimized. Once the warheads or PBVs are removed, the stored warheads can be monitored in the same manner as other components. The silo door can be monitored, for silo-based missiles, to assure that the warheads are not replaced. Mobile missiles can be monitored by periodic inspection or by technical monitoring where the empty space left by the warheads is filled with a monitoring device to confirm that the warheads have not been replaced, provided monitoring does not disclose the location of a significant fraction of the force at one time. If a submarine force does not have the capability to replace warheads at sea, monitoring can consist of inspections before the submarine sails. If warheads can be replaced at sea, periodic inspections at sea or technical monitoring may be necessary, provided monitoring does not disclose the location of a significant fraction of the fleet at one time.

Removing igniters, stabilizing platforms, navigation computers, batteries, or PBV fuel would render the missile inoperable until such components can be replaced. Replacing these items can take several hours for each missile. The exact amount of delay would depend upon the particular missile-component combination. Verifying that these relatively small components have been removed would probably require an inspector to:

- view the removal process in sufficiently close proximity to allow component identification,
- verify that there are not redundant components that can perform the function of the removed components, and
- confirm that the removed component is not replaced when the missile is reassembled.

Once the inspector has confirmed that the component has been removed, monitoring must be done to confirm that the component is not replaced. There are several options for monitoring replacement. One option is monitoring the storage location of the removed components. They can be kept in a known location, which can be monitored to detect removal. Specific monitoring options can include portal perimeter monitoring or monitored vaults for storage. Individual components can have tags that report their position or that activate a sensor if they are removed from a storage area. On the other hand, the existence of duplicate parts would be difficult to monitor. Replacement attempts may be detected by monitoring the silo door or doors for silo-based missiles, since they must be opened to replace most removed components. Monitoring the silo door can be performed with inspections, aircraft or satellite imagery, video surveillance cameras, seals, motion detectors, or beam sensors. If very rigorous monitoring is desired, then sensors that detect attempts to bypass the silo doors and tunnel through the silo walls can be installed. Seals that transmit a signal if they are removed can fill the space left in the missile by the removed components. For mobile missiles, access doors on the missile through which components were removed can be monitored. If the missile is in a canister, then access hatches or lids on the canister can be monitored.

De-targeting involves removing guidance information from the missile. The missile guidance system can be wiped blank of instructions, or instructions that guided the missile to a "harmless" area, such as mid-ocean, can be inserted. This would add extra procedures to the launch process, though the actual time delay would be only a few seconds to minutes, and effective monitoring may not be possible.

Table 3 summarizes component removal issues for silo-based, land-mobile, and submarine-launched ballistic missiles.

Table 3. Discussion of Component Removal

Measure	Force Security	Practicality	Effectiveness	Delay	Verifiability
Booster De-fueling	Silo-based missiles and fueling apparatus would be highly vulnerable during refueling as would submarines and their missiles being refueled in port. If monitoring reveals the location of land-mobile missiles or SLBMs, their vulnerability increases.	This is only practical for liquid-fueled missiles. The removed fuel must be disposed of or stored, which may add cost. An SLBM may have to be unloaded for refueling.	De-fueling is very effective because a missile will not fly without fuel.	Refueling a large missile would take several hours. It might take weeks to fuel the entire force. Submarine-to-port travel time would increase delay, unless refueling at sea is possible.	Aircraft/satellite monitoring or on-site sensors can probably detect refueling. Also silo doors can be monitored if they must be opened for refueling. If a silo has built-in fuel storage, then OSIs or technical on-site monitoring would be needed. If SLBMs can be refueled at sea, monitoring would be a challenge.
Warhead Removal	Survivable, secure storage is necessary. With central storage, the entire force may be vulnerable. Dispersed storage decreases vulnerability. Empty silo storage may be possible for silo missiles. The force is vulnerable to attack during warhead replacement. Monitoring that reveals mobile missile or sub location would increase vulnerability.	If it were necessary to construct new secure, survivable storage facilities, the cost would be high.	This would be very effective.	Reinstalling warheads can take from an hour for mobile missiles to hours for silo and sub missiles. If the warheads are stored remotely, then hours to days of travel time may be added. Delay times of weeks to months for a whole force may be required, depending upon the availability of crews and equipment.	OSIs can confirm warhead removal. Attempts to replace silo-based warheads can be detected by relatively nonintrusive inspection or silo door technical monitoring devices. Inspection or monitoring devices may be required for mobile or sub missiles.
De-targeting	There would be little or no added vulnerability, due to the short re-alerting time.	Targeting is part of a normal launch procedure, so little additional expense would be needed.	De-targeting is very effective but also very easy to reverse.	Target coordinates and other navigational information can be uploaded electronically in a few seconds to minutes.	Access to missile guidance would be needed to verify this measure. Very intrusive OSIs would be necessary. It would be difficult to detect coordinate transfer.

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Table 3. Discussion of Component Removal, continued

Measure	Force Security	Practicality	Effectiveness	Delay	Verifiability
Shroud Removal	Crews replacing shrouds at silos would be vulnerable. Subs would be vulnerable during in-port replacement. Monitoring that reveals the location of a large part of the mobile missile or sub force increases vulnerability.	The shroud may not be removable without removing the warheads also.	The missile may be able to fly without the shroud. Some missiles may not have shrouds.	It would take minutes to hours to replace the shroud.	Shroud removal can be confirmed by OSI. Silo doors can be monitored to detect replacement for silo missiles. Monitoring may require periodic inspections or monitoring devices. Monitoring subs would be the most challenging.
Key Component Removal	Removed components must have secure storage. Security problems with storage would be less than for warheads. Sensitive design information might have to be revealed to ensure the right components are removed. Subs may be vulnerable during replace-ment. Silo missiles would be less vulnerable particularly if the main door were not opened. Monitoring that reveals the location of a large part of mobile or sub missile forces increases vulnerability.	Additional costs might be incurred for component storage. It may be necessary to remove a sub missile from the tube to remove components.	The effectiveness depends upon removal of all the right components. Detailed knowledge of the missile might be needed to ensure that the missile was disabled and that redundant components do not exist.	Component insertion times can vary from minutes to hours. Central storage can add delays of hours to days, because of travel time. Sub travel time must be added if their components must be replaced in port.	OSIs can confirm component removal; OSIs or technical monitoring devices are needed to detect replacement. Monitoring mobile missiles would be more difficult than silo missiles. Submarine monitoring at sea would be particularly difficult.
PBV (Post-Boost Vehicle) de-fueling	If the entire PBV must be removed, then silo crews would be exposed during this operation. If the sub must return to port, the sub be-comes vulnerable. Monitor-ing at sea might reveal the sub's location.	This depends upon the missile having a PBV with an accessible liquid fuel tank.	The missile may still be able to accomplish its mission without the use of the PBV motor.	The time delay would depend upon the specific missile design. If the PBV must be removed for refueling, hours of delay per missile might result. Otherwise, refueling may require minutes.	An OSI would be needed to confirm fuel removal. If the PBV can be refueled while on the missile, monitoring may be very difficult.

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Table 3. Discussion of Component Removal, continued

Measure	Force Security	Practicality	Effectiveness	Delay	Verifiability
Igniter Disconnection, or Safety Pin Insertion	Monitoring that reveals the location of a large part of the missile force increases vulnerability for mobile missiles and subs.	This measure resembles normal maintenance activities and would not involve great expense for silo and mobile missiles, but may not be possible for sub missiles.	This measure would prevent the missile's launch.	It would only take minutes to reconnect the igniters or remove safety pins unless the missile must be removed.	An OSI can confirm igniter disconnection or pin insertion. Periodic inspections or technical monitoring would be required. Monitoring would be inside the silo for silo missiles, and would be particularly difficult for sub missiles.

3.8 Delivery System Removal from Deployment Areas or Launch Sites

3.8.1 Silo-Launched Missiles

Removing silo-based missiles from silos would add significant time delay (hours to days) to a launch procedure. The empty status of the silo can be verified by monitoring the silo door as discussed above. If the missiles are stored on site, a storage facility would be required and the missile would be vulnerable to attack while it is outside of its silo. Storing the missile at a remote site would add delay time and may decrease the missile's vulnerability while out of the silo. It is possible that storage areas can be monitored by aircraft, satellite, or video surveillance or by portal-perimeter monitoring to assure that missiles remain in their storage areas. Another monitoring option might be to attach tags to missiles that transmit an alarm when the missiles are removed from their storage areas.

3.8.2 Land-Mobile Missiles

Removing mobile missiles from TELS would add a significant time delay (hours) to a launch procedure because of the time required to reload the missiles onto their TELs and prepare them for launch. The empty status of the TEL can be verified by inspection or by attaching a missile exclusion monitoring device to the TEL that sounds an alarm or interrupts a "clear" signal if removed. If the missiles were stored at a storage site, the missiles may be vulnerable to attack. Storing the missile at a remote site would add even more delay time and may decrease the missile's vulnerability while removed from its TEL. It is possible that storage areas can be monitored by aircraft, satellite, or video surveillance or by portal monitoring to assure that missiles remain in their storage areas. Marking the missiles with tags that transmit an alarm when removed from their storage areas is another option. A form of mobile storage can be used. A missile can be stored on the vehicle used to load it onto the TEL. The vehicles would park in dispersed locations. If alerted to a missile attack, the transporter crew may be able to put it on the road in a few minutes and avoid destruction from a preemptive strike. In order to implement this type of storage, many more transporters would be required than would be used for routine operations. There would also have to be reliable warning of attack.

It may also be possible to keep TELs in one geographic region and missiles on transporters in another. The initial separation of missiles and TELs can be verified by aircraft or satellite surveillance or by inspectors. Monitoring may be accomplished by having TELs and missile transporters check in periodically with an inspector or by transmitting an encoded signal to verify their general location and then move within their restricted geographical area to avoid being precisely located. The time between checks would have to be shorter than the time required to travel between the two geographical areas. If all possible entrances and exits are monitored, then monitoring all TELs may not be necessary.

It may be possible to move TELS so that their missiles are out of range of potential targets. This would depend upon the existence of an area that is remote enough to be out of range of the targets and large enough that survivability is not impaired. The measure can be monitored by the methods described in the last paragraph. The time between checks would have to be shorter than the time required to travel from the remote region to a launch area.

3.8.3 Submarine-Launched Missiles

Removing SLBMs from missile submarines would add significant time delay (days to weeks) to a launch procedure because of the time required to reload all the missiles. This would have to be done in port or at a protected anchorage. The empty status of a missile submarine can be verified by inspection or possibly by aircraft or satellite monitoring. If the submarine must return to port to reload during a crisis, it would be vulnerable while reloading.

Restricting missile submarines to a patrol area that is out of target range would add significant delay time to a launch procedure. Some methods have been proposed for monitoring the submarine's location without cueing antisubmarine warfare (ASW) forces. Missile submarines can appear to an inspector (possibly located on a ship or island) at random times or at random locations at the inspector's request or at the submarine commander's discretion. Such a scheme may allow the submarine to be unlocatable during most of its patrol while confirming its general location. On the other hand, the submarine is vulnerable when it surfaces for inspection, and giving ASW assets a fix at a specific time and location may enhance their capability to track the submarine when it continues its patrol. ASW units may have to be excluded by agreement from specific ocean areas designated as submarine sanctuaries. It is possible that disclosing the location of a single submarine at one time is acceptable as long as the location of others is unknown.

Another possible measure would be to deploy sensors around the patrol area so submarines entering or leaving the area would be detected. The location of a submarine within the area, however, would not be monitored. This would be technically very challenging.

Table 4 discusses issues for removing delivery systems from launch areas.

3.9 Warhead or Delivery System Disassembly

This measure can be applied to all three basing modes. Disassembly would create the greatest time delay of any de-alert measure to launching a strategic strike. The specific time delay depends on the extent of disassembly and can range from hours to months. Parts can be stored in separate storage areas that have portal-perimeter monitoring and periodic inspections. Small parts like warhead components can be put into containers that are sealed, tagged, and placed in rooms with video surveillance and intrusion alarms.

Table 5 discusses missile disassembly in terms of the five evaluation criteria.

Table 4. Discussion of Delivery System Removal from Launch Areas

Measure	Force Security	Practicality	Effectiveness	Delay	Verifiability
Missile Removal from Launcher	Survivable, secure storage is necessary. Central storage may make the entire force vulnerable. Dispersed storage decreases vulnerability. If mobile storage is used for mobile missiles, the TELS and missiles must have assured access to each other for re-alerting. Subs must be in port or at a protected anchorage to reload. This would increase the vulnerability of the sub while reloading. Monitoring must not divulge the location of a significant fraction of the mobile or sub force at one time.	The cost of missile storage would be considerable for a large force. If mobile storage is used, additional transporters for dispersion of missiles may be required.	Removing missiles from silos is a very effective means of delaying launch unless clandestine launchers or missiles are constructed.	Replacing a silo-based missile would take hours to days. Central storage can add several days. Replacing a whole force may require months. A missile may be reloaded on a TEL in one to a few hours. Days to weeks would be needed to re-alert a large mobile force, depending upon the equipment available. It would take up to a day per submarine to reload. Travel time to and from the port can be days.	OSI or aircraft/satellite monitoring can confirm missile removal. Both removed missiles and launchers must be monitored, either by OSIs or technical monitoring.
TELs Moved Out of Range of Targets	If routes between hide areas and launch areas are known, they would be subject to attack and would increase force vulnerability. Monitoring must not disclose the location of the TEL.	Suitable deployment areas which are out of range of targets and suitable for hiding TELs must be available.	If the missile range were large enough, there would be no areas out of range of targets.	A delay of hours to days can be gained if the deployment areas are sufficiently distant from launch areas.	TELs that leave their designated areas must be detected. Choke-point monitoring may be possible, but very flat terrain can preclude this.
Remote Patrol Areas	Sub location must be known well enough to confirm it is in patrol area, but not well enough to cue ASW units. Exclusion of ASW units from the remote patrol area may be needed. Sub vulnerability may be increased during transit to patrol areas.	A perimeter monitoring system may not be technically feasible.	The patrol areas must be out of range of targets. At port and during transit, potential targets might be within range of the submarine missiles.	Depending upon the location of the area, hours to days of delay may be possible because of transit time.	Confirmation of the subs as being within the area is necessary. Surfacing the subs at random times to verify their location may be feasible.

Table 5. Discussion of Warhead or Delivery System Disassembly

Measure	Force Security	Practicality	Effectiveness	Delay	Verifiability
Missile Disassembly	Safe, secure storage is needed for the large numbers of parts produced by disassembly. Attack upon a few storage or re-assembly facilities can prevent re-alerting.	There would be considerable cost involved in disassembling missiles and storing the parts.	Unless missiles are assembled outside the monitoring system, this would be very effective.	The delay for re-assembly can range from hours to months, depending upon the extent of disassembly, the size of the force, and the resources available for re-assembly.	Somewhat intrusive OSIs would be needed to verify disassembly. Disassembled missiles can be monitored using inspectors or portal-perimeter monitoring. It may be necessary to monitor missile-manufacturing plants to ensure that missiles are not fabricated outside the monitoring regime. It may be difficult to verify that there are no missiles at undeclared sites or missiles purchased from third parties.

3.10 Evaluation Tables for Missile De-Alerting Measures

This section gives the authors' qualitative evaluation of potential de-alerting measures, given that a decision to de-alert has been made. Each measure is evaluated for each of the evaluation criteria discussed earlier. The evaluation results are presented in three tables. These tables correspond to different types of missiles: silo-based missiles, land-mobile missiles, and submarine-launched missiles. This division was made because some de-alerting issues are significantly different depending upon the type of launcher considered. Colored shapes represent the scores for each measure. A green square indicates that a proposed de-alerting measure appears to have acceptable qualities as measured by that particular criterion. For example, a green rating for a measure evaluated against the force security criterion indicates that the measure should not greatly increase force vulnerability. A yellow (diamond shape) rating indicates that the measure may be acceptable, but there are some issues that must be resolved or there are some tradeoffs that would have to be made to implement that measure successfully. A red rating indicates major shortcomings in that particular area. In addition to the individual criterion ratings, an overall rating is given, which reflects the authors' judgement as to whether the overall plausibility of a candidate de-alerting measure is sufficient to merit further study. The overall rating is based on the individual criterion ratings but does not use a specific set of weights. The authors looked for "show stoppers" among the individual criteria and made judgements about which of the criteria were most important in each individual case. Another group of evaluators who have different judgements about which criteria are most important would very likely come to different conclusions. The measures were judged based on their de-alerting merits, and some measures that were judged to have low de-alerting merit may have excellent merit relative to a different objective. For example, de-targeting has low de-alerting merit because it adds little time to a launch and it is difficult to verify, but it may be an excellent safety or confidence building measure. A final column in the table indicates in which of the earlier de-alerting issues tables this measure was discussed.

The tables represent ratings for a nonspecific context and for generic missile systems. In an actual de-alerting agreement, the context and details of specific missile systems may alter the ratings. For example, booster de-fueling as a de-alerting measure is not practical if one or both parties possess only solid-fueled boosters. These tables are intended to indicate which de-alerting measures are worth further study, rather than a detailed guide as to which measure is optimal for a given specific situation.

In Table 6, some possible de-alerting measures have an overall red rating. Post-launch controls were rated poorly because they must be very reliable to be effective, because they added no time delay to a launch, and because there is no transparency measure associated with their use. Timers were considered to be either too easy to circumvent or too intrusive if they were integrated into the missile to avoid circumvention. While de-targeting is useful as a confidence building measure, it introduces little delay and extremely intrusive measures would be required for verification. Missile disassembly would be very costly and the excessive time required for re-alerting can produce a dangerous re-alerting race.

Other measures produced better evaluations. The highest overall evaluations were given to warhead and component removal because they have the potential to be effective, verifiable, and relatively inexpensive. Actual implementation to a particular missile system, however, would require detailed study.

Those measures that received red ratings for silo-based missiles also received poor ratings for land-mobile missiles. Because of the greater difficulty of monitoring mobile missile de-alerting, there were substantial unresolved monitoring issues for all de-alerting measures and no measure received an overall rating greater than yellow. If monitoring systems can be designed that would not increase the vulnerability of mobile systems, then higher assessments would be generated for some de-alerting measures.

The extreme difficulty of monitoring submarine-based missile de-alerting without endangering the launch platform drove the overall scores of most candidate de-alerting measures to red ratings. Only one possible measure—remote patrol areas—appears to warrant further study with present technology. To make other de-alerting measures feasible, methods of communicating monitoring information without disclosing the position of the submarine must be found. This would require considerable research.

Table 6. Technical Evaluation of De-Alerting Measures for Silo-Based Missiles

Measure	Force Security	Practicality	Effectiveness	Delay	Verifiability	Overall	Issues
Post-Launch Controls			○	○	○	○	See Table 1.
Delay Timer	○		○	□	○	○	See Table 2.
Silo Door Obstacles	□	□			□		See Table 2.
Silo Door Disabling	□						See Table 2.
Flight Impediments	□						See Table 2.
Aero-Shroud Removal	□	□			□		See Table 3.
LAD Removal	□	□	□				See Table 3.
Warhead Removal	□		□	□	□	□	See Table 3.
Booster Defueling			□	□	□		See Table 3.
PBV Defueling	□						See Table 3.
Detargeting	□	□		●	●	●	See Table 3.
Component Removal	□	□	□		□	□	See Table 3.
Booster Removal and Remote Storage			□	□	□		See Table 4.
Missile Disassembly	○	○	□	□	□	○	See Table 5.

□ May be acceptable

Issues to be resolved

○ Major shortcomings

Table 7. Technical Evaluation of De-Alerting Measures for Land-Mobile Missiles

Measure	Force Security	Practicality	Effectiveness	Delay	Verifiability	Overall	Issues
Post-Launch Controls			●	●	●	●	See Table 1.
Delay Timer	●		●	□	●	●	See Table 2.
TEL Disabling and Obstacles	□	□					See Table 2.
Flight Impediments	□						See Table 2.
Aero-Shroud Removal	□	□					See Table 3.
LAD Removal	□	□	□				See Table 3.
Warhead Removal	□		□				See Table 3.
Booster Defueling			□	□	□		See Table 3.
Detargeting	□	□		●	●	●	See Table 3.
Component Removal	□	□	□				See Table 3.
Remote Deployment Areas	□						See Table 4.
Booster Removal and Remote Storage	□		□	□			See Table 4.
Missile Disassembly	●	●	□	□	□	●	See Table 5.

□ May be acceptable
Issues to be resolved
● Major shortcomings

De-Alerting Strategic Ballistic Missiles

Table 8. Technical Evaluation of De-Alerting Measures for Submarine-Based Missiles

Measure	Force Security	Practicality	Effectiveness	Delay	Verifiability	Overall	Issues
Post-Launch Controls			○	○	○	○	See Table 1.
Delay Timer	○		○	□	○	○	See Table 2.
Launch Tube Obstructions or Welding	□	□			○	○	See Table 2.
Flight Impediments	□				○	●	See Table 2.
Aero-shroud Removal	□	□			○	●	See Table 3.
LAD Removal	□	□	□		○	○	See Table 2.
Warhead Removal (Onboard storage)	□	○	□		○	○	See Table 3.
Warhead Removal (Remote storage)			□	□	○	○	See Table 3.
Booster Defueling			□	□	○	○	See Table 3.
PBV Defueling	□				○	○	See Table 3.
Detargeting	□	□		○	○	○	See Table 3.
Component Removal	□	□	□		○	○	See Table 3.
Remote Patrol Area	□			□			See Table 4.
Missile Removal and Remote Storage	○		□	□	□	○	See Table 4.
Missile Disassembly	●	○	□	□	□	●	See Table 5.

□ May be acceptable
Issues to be resolved
○ Major shortcomings

4. Additional Issues

It may not be possible to achieve agreement upon de-alerting the total missile force of a country; however, de-alerting a portion of the missile force may still be possible. Some part of the missile force can be kept at alert while the rest is de-alerted. While this would not totally solve the problem of accidental or unauthorized launch of the alerted force, it would reduce opportunities for those events to occur, and it would reduce fears of a massive surprise attack.

Asymmetries between strategic forces may present a challenge. The fact that the U.S. placed greater emphasis upon SLBMs in their strategic force and the Russians emphasized ICBMs complicated the negotiations of the START treaties. Asymmetries would also complicate negotiating a de-alerting agreement. The time required to re-alert the two forces must be similar in order to prevent instabilities during a re-alerting process. The greater challenges presented in monitoring land-mobile and SLBM forces might make de-alerting agreements between countries choosing these types of forces and countries choosing silo-based missiles more difficult to achieve. An additional difficulty in the U.S.-Russian context is the unique nature of the Russian SLBM force. These missiles are believed to have sufficient range that they can be fired from port. A portion of the force is believed to remain on alert in port. While in port, submarine missile de-alerting measures may be easier to monitor, but de-alerting measures may significantly increase the force's vulnerability and decrease its deterrent value. Resource constraints may prevent the Russian submarine force from participating in remote patrol area de-alerting regimes. Concern about vulnerability may prevent them from participating in in-port de-alerting regimes. These issues must be taken into account when considering de-alerting the Russian SLBM force.

5. Conclusions

This paper defines de-alerting measures as reversible actions taken to increase the time and effort required to launch a strategic ballistic missile. The goal of de-alerting is to reduce the risk of accidental, unauthorized, or ill-considered launches, and to allow time for negotiation and reconsideration during crises.

To gain the greatest benefit, de-alerting measures must significantly increase the time and effort required to launch strategic weapons and must be verifiable. They should not decrease the safety or security of strategic weapons, and they should not decrease deterrent value. They should allow a stable return to alert status, if necessary. De-alerting measures should satisfy specific criteria of force security, practicality, effectiveness, significant delay (hours to days), and verifiability.

This study considered a wide range of de-alerting measures. Silo-launched missiles lend themselves most readily to de-alerting verification, because communications necessary for monitoring do not increase the vulnerability of the weapons by a significant amount, although the de-alerting measures themselves may increase vulnerability. In addition, the silo itself restricts access to the missile inside, which eases the task of monitoring to confirm that removed components have not been replaced. Land-mobile missile de-alerting measures would be more challenging to monitor, because communication measures that may disclose the launcher's location would potentially increase their vulnerability. Submarine-launched missile de-alerting measures would be extremely challenging if not impossible to monitor without increasing the submarine's vulnerability. Tradeoffs between confidence in the monitoring method and the vulnerability of the force would be necessary.

References

ACR, 97: *The Arms Control Reporter*, Institute for Defense and Disarmament Studies, Cambridge, Massachusetts, 1997.

Ahrens, 1997: Brandon Ahrens and Anna Hadley, *A Study of Technical Measures to Support De-alerting*, Sandia National Laboratories, to be published.

Arfman, 1993: John F. Arfman, Jr., *De-Alerting and Monitoring: A Conceptual Framework*, Sàndia National Laboratories, White Paper, May 28, 1993.

Blair, 1993: Bruce G. Blair, *The Logic of Accidental Nuclear War*, Brookings Institution, Washington, D.C., 1993.

Blair, 1995: Bruce G. Blair, *Global Zero Alert for Nuclear Forces*, Brookings Institution, Washington, D.C., 1995.

Burns, 1993: *Encyclopedia of Arms Control and Disarmament*, Charles Scribner's Sons, New York, 1993.

Carter, 1987: Ashton B. Carter et al, eds., *Managing Nuclear Operations*, Brookings Institution, Washington, D.C., 1987.

Gregory, 1990: Shaun Gregory, *The Hidden Cost of Deterrence: Nuclear Weapons Accidents*, Brassey's, London, 1990.

Norris, 1994: Robert Norris, et al, *Nuclear Weapons Databook: Volume V, British, French, and Chinese Nuclear Weapons*, Westview, San Francisco, 1994.

SIPRI, 1996: Stockholm International Peace Research Institute, *SIPRI Yearbook 1996: Armaments, Disarmament and International Security*, Oxford University Press, 1996.

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