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# Verifying Missile Proliferation in Northeast Asia

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# Verifying Missile Non-Proliferation in Northeast Asia

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## Abstract

Missiles are attractive weapon systems because of their flexibility, survivability, and relatively low cost. Consequently, many nations are seeking to build missile forces resulting in regional arms races. Missile forces can be both stabilizing (e.g., providing a survivable force for deterrence) and destabilizing (e.g., creating strategic asymmetries). Efforts to control missile proliferation must account for these effects. A number of strategies to control the destabilizing effects of missiles were developed during the Cold War. Some of these strategies are applicable to regional missile control but new approaches, tailored to regional geographic and security conditions, are needed. Regional missile nonproliferation can be pursued in a variety of ways:

- Reducing the demand for missiles by decreasing the perception of national threats
- Restricting the export of missiles and associated equipment by supplier countries
- Restricting information describing missile technology
- Limiting missile development activities such as flight or engine tests
- Restricting the operational deployment of existing missile forces
- Reducing existing missile forces by number and/or type.

Even when development is complete, limits on deployment within range of potential targets or limits on operational readiness can help stabilize potential missile confrontations.

Implementing these strategies often involves the collection and exchange of information about activities related to missile development or deployment. Monitoring is the process of collecting information used to for subsequent verification of commitments. A systematic approach to implementing verification is presented that identifies areas where monitoring could support missile nonproliferation agreements. The paper presents both non-technical and technical techniques for monitoring. Examples of non-technical techniques are declarations about planned test launches or on-site inspections. Examples of technical monitoring include remote monitoring (i.e., a sensor that is physically present at a facility) and remote sensing (i.e., a sensor that records activity without being physically present at a facility).

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# 1. Introduction

Missiles are an important component in the world's military arsenals and a source of concern in Northeast Asia. They are of concern because of their long range, potential to deliver both high explosive and weapon of mass destruction (WMD – nuclear, chemical, biological) warheads, and the difficulty in defending against them once launched. Within a military structure missiles can have a role for war fighting and deterrence. In addition, missiles are used as nationalist symbols. Many nations in the world possess short-range missiles whose mission is to support activities on the battlefield. The range of this class of missiles is commonly defined to be 150 km or less.[1] There are currently 34 countries in the world that possess ballistic missiles with ranges greater than 150 km. Almost one third of these countries are located in Asia: China, India, Kazakhstan, North Korea, Pakistan, South Korea, Taiwan, and Vietnam.

The political and psychological reaction to missiles can be out of proportion to their actual effect. This is largely a response to the public's feeling of helplessness. During the 1944-45 German missile campaign against England, the inaccurate V-2 missile delivered less explosive ordinance than the V-1 "buzz bomb" (an early cruise missile) and manned bombers. Yet the V-2's ability to strike London with 1000 kg warheads and no warning forced Prime Minister Churchill to redirect allied bombers away from strategic targets in Germany to a largely ineffective campaign against launch sites. Forty-six years later, the sporadic Iraqi Scud missile campaign in the 1991 Gulf War caused no significant military damage but allied commanders were similarly forced to devote significant resources to detecting and attacking the missile launchers with marginal success.

Currently, the types of missiles possessed by most countries do not have sufficient accuracy to attack point targets using conventional warheads with a high probability of success, although they can have significant detrimental effects on the morale of civilian populations and so might be used as terror weapons. The advance of technology has raised the prospect of more accurate guidance becoming available to many countries. Should this happen, ballistic missiles could be used effectively against tactical military targets. This might increase the motivation of many countries to acquire more and different types of missiles.

This paper, while noting the strategic and political context of Northeast Asia, focuses on strategies and techniques for controlling the deployment and spread of missiles with greater than battlefield range. It focuses especially on the role that monitoring technology and procedures could play.

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[1] There are various definitions of missile range categories. The authors use the classification categories defined by the Centre for Defence and International Studies (UK) (www.cdiss.org/bmrange.htm).

| | |
|---|---|
| Battlefield Short Range Ballistic Missile (BSRBM): | up to 150 km |
| Short-Range Ballistic Missile (SRBM): | 150 - 800 km |
| Medium-Range Ballistic Missile (MRBM): | 800 - 2400 km |
| Intermediate-Range Ballistic Missile (IRBM): | 2400 - 5500 km |
| Intercontinental Ballistic Missile (ICBM): | over 5500 km |

A number of concepts are outlined for achieving these objectives. The effectiveness of each concept depends on a complicated mix of political, technical, and operational factors.

## 2. Missile Characteristics

The terminology used to describe missiles is somewhat complex. In general, a *rocket* is a self-propelled cylinder using liquid or solid fuel. Similarly, a *missile* is a flying object intended to strike a designated target. In modern military terminology, a rocket is an unguided weapon propelled by a rocket engine. Military rockets thus take many forms and are launched from the shoulders of individual soldiers, vehicles, aircraft, and ships. Their mission is similar to that of artillery and they have ranges less than 75 km. A missile in the military context is a rocket with a guidance system that adjusts its flight path to the target after launch. This paper is oriented toward surface-to-surface missiles and excludes air-to-air, air-to-surface, and surface-to-air systems because virtually all these missiles are of battlefield range. Space launch vehicles are specialized missiles that are usually too large or logistically complex for military applications. Military missiles fall into two categories: ballistic and cruise. Ballistic missiles have an initial powered boost phase followed by supersonic free flight along a high, arcing trajectory. Guidance occurs during the boost phase and, in more advanced systems, during the re-entry phase. The term "cruise missile" refers to unmanned, automatically guided, self-propelled air-breathing vehicles that sustain flight through the use of aerodynamic lift.

The following sections describe some of the key parameters associated with missile operations. These parameters affect the development of options to control missile deployment and proliferation.

### *2.1. Short Time of Flight*

Ballistic missiles are the fastest means to deliver a warhead to a target at long range. In a matter of a few minutes, a missile can cover a distance of hundreds of kilometers as illustrated in Figure 1. Short time of flight minimizes the chance of a target moving before it is struck and also minimizes the warning time for the defenders. High speed also decreases the effectiveness of defensive measures.

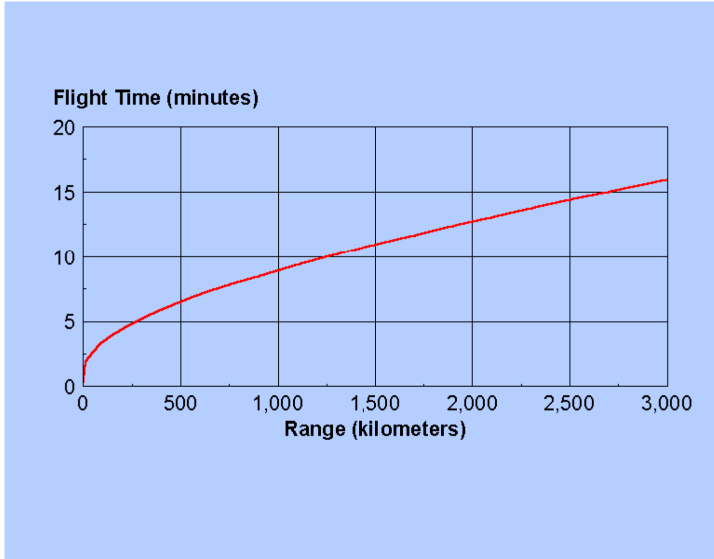


*Figure 1: Range Versus Time for Ballistic Missiles*

## 2.2. Range

A medium-range missile with a 2000-km range could threaten the majority of Northeast Asia if fired from any location within the region. Long-range missile technology, however, is complex. The technical requirements for a missile that could deliver a large payload to a target at 3,000 km are much more demanding than those for a 200 to 300-km range missile (the range of the infamous SCUD). A long-range missile requires more powerful engines; a stronger, lighter structure; a more precise guidance system; and more protection against aerodynamic heating than does a short-range missile. Mere extrapolation of short-range rocket technologies is not sufficient, as demonstrated by the Iraqi Al-Hussein missile. This missile was a modified Scud design with a reduced payload and stretched fuel tanks to achieve a longer range. While it attained these ranges, the increased aerodynamic loads associated with higher speeds usually caused these missiles to break up on reentry into the atmosphere.

## 2.3. Pre-launch Survivability

Missiles can be made difficult to destroy before launch. The US and the Soviet Union protected their intercontinental ballistic missiles (ICBMs) by installing them in hardened underground silos or by deploying them as submarine-launched ballistic missiles (SLBMs). Other concepts for protecting missiles include basing them in caves or tunnels. Transporter-erector-launchers (TEL) are common for all but the largest missiles and constitute relatively small, hard-to-find, mobile targets. The currently preferred option for regional ballistic missiles is the mobile launcher. This method of deployment is cheaper than hardened, fixed silos and, as was shown in the 1991 Gulf War, highly survivable. Missiles can be deployed in various stages of readiness. They may be kept ready for firing within minutes, although continual maintenance must be performed. When a low state of alert is acceptable, missiles can be deployed without fuel or in a partially disassembled state.

### 2.4. Accuracy

Current ballistic missiles in the possession of regional powers are relatively inaccurate and therefore have limited utility against small military targets when used with conventional warheads. The circular error probable (CEP), the most common statistical measure of missile accuracy, is the radius of a circle within which 50 percent of the missiles aimed at the center of the circle will strike. Missiles currently in the stockpiles of regional powers have CEPs in the range of 300 to 1000 m. Thus, warheads with relatively large effects radii, such as WMD, are needed to assure a significant probability of destroying the target. Advances in guidance technology, including the use of the Global Positioning System (GPS), may reduce these CEPs to less than 100 m. Should this occur, conventional warhead effectiveness against unhardened tactical military targets, such as supply dumps, would be greatly increased.

### 2.5. Autonomy After Launch

Once launched, missiles are fully autonomous and cannot be recalled or diverted. Because a missile does not accept external commands, there is no possibility of jamming or spoofing the guidance (although if future missiles rely on GPS-based guidance, they may become vulnerable to jamming). The lack of control once a missile is launched reduces operational flexibility. There are many cases of manned aircraft being recalled or diverted to other targets while in the air.

### 2.6. Response Time

Given that missile flight times are only a few minutes, warning times are even less, due to the time required for sensors to detect an attacking missile already in flight. Response times are further reduced because of delays in communicating alerts to decision makers, assessing information, making decisions, and finally giving orders on how to respond. A strategic response might be to adapt a launch-on-warning posture in which countries may respond prematurely before having time to fully assess the warning information received.

During the Cold War, a number of incidents involved accidents and misinterpretations related to nuclear weapons and delivery systems. An example of misinterpretation of missile-related data occurred in 1979 when a training tape showing a missile attack was accidentally placed in the live warning system.[2] Six minutes were needed to assess the threat before determining it was false. While that was sufficient time in the context of long-range US/USSR intercontinental missiles, such time would not be available with the short flight times in regional contexts. A 1983 Senate investigation revealed that there were 151 false alarms in a six-month period, the longest of which was six minutes.[3] These concerns contributed to agreement on the Intermediate Range Nuclear Forces Treaty (INF). As late as 1995,

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[2] Scott D. Sagan, *The Limits of Safety: Organizations, Accidents and Nuclear Weapons* (Princeton: Princeton University Press, 1993).

[3] Alex Deley, "Are Nuclear First-Strike and/or Launch on Warning Policies Becoming Inevitable?, " Congressional Briefing Paper, (Bertrand Russell Society, Chicago, April 1983).

Russian officials misinterpreted the launch of a Norwegian–American research rocket. Despite prior notification, Russian authorities were not informed and used their internal hotline link to discuss a possible retaliatory strike.[4]

# 3. A Framework for the Control of Missiles

Measures to reduce instability or tension associated with the deployment of missiles can take the form of transparency or arms control. Existing and conceptual missile control agreements consist of a number of elements and can be analyzed by using a systematic structure. Elements of such a structure define the topic and scope of the agreement, actions to be taken to control missile-related activities and parameters under the agreement, specific items to be controlled, and the locations where actions to control these items will be applied. The choices made by the parties for these elements determine the structure for the agreement.

## 3.1. Transparency

Actions to increase transparency can be used to build confidence between adversaries and sometimes to build the foundation for subsequent formal arms control agreements. The United Nations defines transparency as "The systematic provision of information about specific aspects of military activities under formal or informal international arrangements."[5] Transparency can be unilateral or bilateral, and transparency agreements are not typically ratified by the governments. Sometimes it is in the best interest of one's own security to act unilaterally to avoid misinterpretation of intent. The concept of transparency, however, has bounds. In practice, there is a role for both transparency and opacity in missile threat reduction. While most of the emphasis in this paper is on implementing ways of collecting and sharing information to increase stability, choosing *not* to share certain information can enhance stability. Such information includes system deployment locations, system vulnerabilities, and performance capabilities.

When planning transparency actions, a matrix of data sharing actions and stability/instability impacts needs to be assessed. Figure 2 shows examples of actions that fit the quadrants of a stability/transparency matrix. The destabilizing examples emphasize asymmetries in capabilities and failure to reveal important information that could lead to misinterpretation. The stabilizing examples show actions intended to avoid misinterpretation and to minimize vulnerabilities of critical assets. Generally, transparency leads to greater stability when the following criteria are achieved as a result of providing information:

- Increased symmetry of forces and/or capabilities
- Increased warning time or reduced likelihood of preemption success
- Reduced likelihood of misinterpretation of intent
- Reduced vulnerabilities for either side.

[4] Elaine Monaghan, "Russia, US, Cut Risk of Inadvertent Nuclear Strike," *Reuters*, 16 December 2000.
[5] United Nations Experts Group, *Study on Ways and Means of Promoting Transparency in International Transfers of Conventional Arms,* Report to the Secretary General, UN Document A/46/301, September 9, 1991.

| | | |
|---|---|---|
| DEMONSTRATE EXPANDED MISSILE RANGE AND PAYLOAD CAPABILITIES (*promotes arms race*) | PROVIDE MISSILE LAUNCH NOTIFICATION **(***avoids misinterpretation***)** | **TRANSPARENT** |
| AVOID DIALOGUE ON MISSILE ALERT STATUS DURING CONVENTIONAL ARMED CONFLICT **(***risks misinterpretation***)** | AVOID REVEALING COMPLETE LIST OF WARHEAD STORAGE LOCATIONS (*minimizes vulnerabilities*) | **OPAQUE** |
| **DESTABILIZING** | **STABILIZING** | |

*Figure 2: Example of a Stability/Transparency Matrix*

### 3.2. Constructing Arms Control Agreements for Missiles

Arms control is normally implemented in formal and ratified agreements that commit the signatories to conduct specified actions (e.g., eliminate a defined type of weapon). Arms control is accompanied by verification activities that evaluate compliance with mandated commitments. A standard conceptual approach helps to generate strategies for missile control agreements. Six steps describe the process of constructing an agreement:

1. Determine the topic of concern of the agreement.
2. Select the geographic area where the agreement is to be applied. The scope can be global, regional, or bilateral.
3. Define the actions to be taken in the agreement and the type of information to be exchanged.
4. Identify the parameters that define the above actions. This step is used define the objectives for subsequent monitoring and verification.
5. Identify the specific items to which the above actions are to be applied. For example, one agreement may only deal with complete missiles, while another agreement might control missile components.
6. Specify the point(s) in the missile life cycle where the actions defined above are to be applied.

Missile systems have a life cycle moving from the research stage to retirement, as shown in Figure 3. Specific actions are easier to implement at some stages than at others. For example, while it may be difficult to determine the state of research, rocket or missile tests may be observed, counted, and measured.

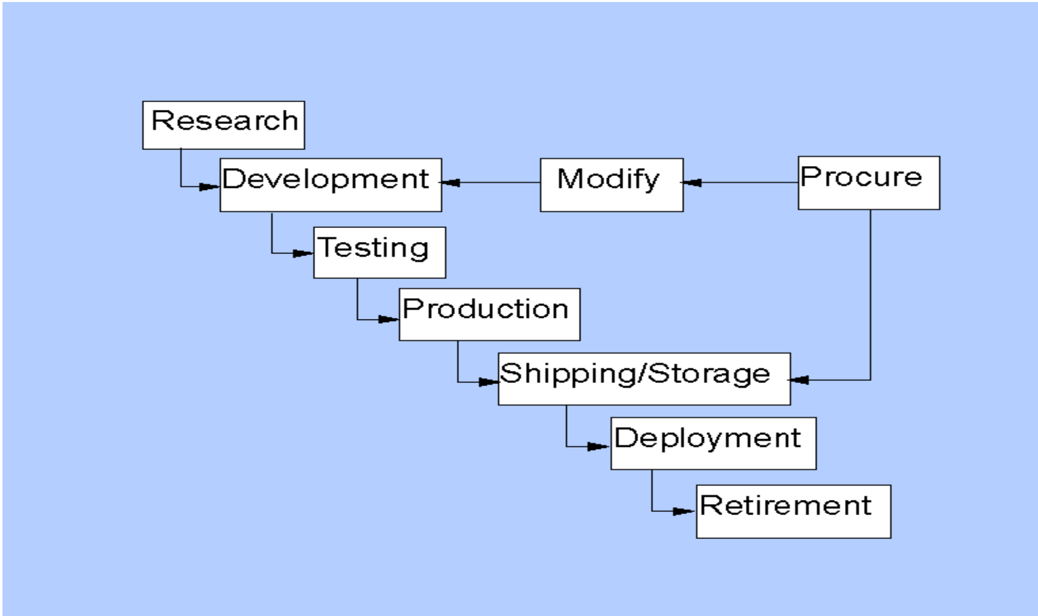


*Figure 3.  The Missile Life Cycle*

Figure 4 shows a list of choices from which the basic structure of a missile agreement can be constructed. The choice of items from these lists will determine the kinds of actions required by an agreement.

The process is illustrated in Figure 5 by shading the applicable elements for the 1987 INF Treaty. The INF treaty eliminated an entire category of weapons: ground-launched ballistic and cruise missiles with ranges between 500 and 5500 km. Both launchers and missiles were eliminated, and the agreement obligated the parties not to produce, test, or deploy these systems, thus covering three phases of the life cycle.

| 1. Topic | 2. Scope | 3. Action | 4. Action Parameters | 5. Specific Items | 6. Point in Life Cycle |
|---|---|---|---|---|---|
| Ballistic Missiles | Global | Limit | Quantity | Complete Systems | Research |
| | | | | | Development |
| | | | Physical Parameters | Components/ Materials | Production |
| Cruise Missiles | Multilateral | Promote | | | Test |
| | | | Location | Facilities | Storage |
| | | | | Processes/ Activities | Transfer |
| Space Launch Vehicles | Bilateral | Inform | Operations/ Use | | Deployment |
| | | | | Movements | Use |
| | | | | | Retirement |

*Figure 4: Elements of a Missile Control Agreement*

| 1. Topic | 2. Scope | 3. Action | 4. Action Parameters | 5. Specific Items | 6. Point in Life Cycle |
|---|---|---|---|---|---|
| Ballistic Missiles | Global | Limit | Quantity | Complete Systems | Research |
| | | | | | Development |
| | | | Physical Parameters | Components/ Materials | Production |
| Cruise Missiles | Multilateral | Promote | | | Test |
| | | | Location | Facilities | Storage |
| | | | | Processes/ Activities | Transfer |
| Space Launch Vehicles | Bilateral | Inform | Operations/ Use | | Deployment |
| | | | | Movements | Use |
| | | | | | Retirement |

*Figure 5. Functional Structure of the INF Treaty*

# 4. Monitoring Techniques

## *4.1. Overview*

Monitoring is the collection of information used to confirm the actions to which the parties committed in an agreement. Information can be collected through declarations, inspectors, and sensors. Monitoring also can be incorporated in less formal transparency strategies. The process of monitoring can be conducted unilaterally or cooperatively with other parties.

Most nations are not willing to rely solely upon cooperative means to monitor items of national security concern. They use their intelligence systems and national technical means (NTM) to complement and confirm information that cooperative monitoring collects. NTM and cooperative monitoring are not inherently in conflict because each collects independent and mutually reinforcing information. Nations base their decisions on compliance in international agreements on the full spectrum of information available to them. For example, the US and USSR agreed in the 1972 Strategic Arms Limitation Treaty (SALT) to use the NTM of each country to monitor the agreement (primarily images from satellites to count missile silos).

There are two major steps in the design of a monitoring system. The first is determining the "observables" of interest. Observables are physical characteristics that can be measured by human or technical means. The nature of the observables depends on the terms of the agreement. For example, under the SALT agreement, the number of missile silos was a major observable. For the Missile Technology Control Regime (MTCR), an observable would be the presence of rocket motors in a cargo ship. In general, observables fall into the five categories shown below:

1. Presence or absence of specific items of interest
2. Number of specific items of interest
3. Location of specific items of interest
4. Physical characteristics of specific items of interest
5. Movement of specific items of interest.

The second step in designing a monitoring system is to select the types of monitoring equipment to be used to monitor the observables. Equipment selection must account for operational factors including:

- Physical characteristics of the observable (e.g., weight, length)
- Active area and range of the sensor(s)
- Physical environment of the sensor during operation
- Reliability of sensors and communication equipment
- Degree of intrusiveness during operation
- Impact of monitoring on government and civilian activities.

## *4.2. Non-technical Approaches to Monitoring*

### 4.2.1. Declarations

Declarations and notifications can be useful confidence-building measures (CBMs) associated with missile development and deployment. Missile quantities, movements, test launches, and exercises may be declared in order to avoid the risks associated with misinterpretation of intent. Even Pakistan and India, which have a long history of conflict, have recognized the value of notifications associated with missile testing. The 1999 Lahore Memorandum of Understanding stated, "The two sides undertake to provide each other with advance notification in respect of ballistic missile flight tests, and shall conclude a bilateral agreement in this regard." This practice was continued during the crisis of 2002. Notification agreements have been an important element of US–Russia nuclear cooperation. The two countries agreed in 1991 under the first Strategic Arms Reduction Treaty (START) to inform the other about launches of intercontinental and submarine-launched ballistic missiles. A 2000 memorandum of understanding expanded the requirement to include shorter-range ballistic missiles, sounding and research rockets, and most space launch vehicles.[6]

In February 2002 more than 80 countries met to evaluate an International Code of Conduct (ICoC) Against Ballistic Missile Proliferation. This proposed political agreement would have each signatory outline its ballistic missile program once a year and provide notification of ballistic missile tests.[7]

### 4.2.2. On-Site Inspection

The first systematic use of inspectors to assess conditions at military-related facilities was conducted under the 1919 Treaty of Versailles to implement the demilitarization of Germany. On-site inspection is a feature of numerous modern treaties, including the INF and START treaties as illustrated in Figure 6. On-site inspection requires access to a facility, and the degree of access is commonly called *intrusiveness*. Intrusiveness can be defined as the degree of physical access of the monitoring regime (human and/or technical) to the territory, facilities, and controlled systems of the parties to an agreement. It can also include the type of information collected, the duration of information collection, the potential for national security information unrelated to the treaty to be collected, and the disruptive effect of monitoring on facility operations. An advantage of human inspection is that trained observers can evaluate information and detect indications of noncompliance immediately. In addition, the interpersonal contact between inspectors and hosts can build trust. These indications may be subtle, suspicious incidents or non-routine activities rather than blatant noncompliance.

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[6] Elaine Monaghan, "Russia, US, Cut Risk of Inadvertent Nuclear Strike," *Reuters*, 16 December 2000.
[7] "Rules for the Road: The International Code of Conduct Against Ballistic Missile Proliferation," *Disarmament Diplomacy*, Issue No. 63, March-April 2002.

*Figure 6: An INF Inspection to Verify the Destruction of Soviet SS-25 Missiles*

On-site inspectors may use a variety of portable data collection and analysis equipment to assist their observations. This equipment can include cameras, tape measures, radiation and chemical detectors, and equipment to obtain physical samples.

A variant of on-site inspection is the examination of written records. If access to genuine records is allowed a detailed picture of an organization and its activities can be derived. The examination of internal government records is considered very intrusive, and destruction, concealment, or fabrication of records is a risk.

## *4.3. Technical Approaches to Monitoring*

### 4.3.1. Remote Monitoring

Remote monitoring is the collection of data by sensors and the transmission of that data from the point of collection to another location for evaluation. That location could be within the facility being monitored or it could be on the other side of the world. Sensors are combined and integrated into a system to monitor and report a specific activity while ignoring unrelated activity. Data can be collected continually or only when activity occurs. Layers of monitoring are sometimes used. For example, the activation of a magnetic sensor (caused by the entry of a ferrous metal object into the sensor's active area) can command a video camera to take an image to determine the identity of the object (e.g., to distinguish between a bus and a TEL). Figure 7 is an example of a video image taken at a nuclear storage facility when a motion sensor detected people entering the storage vault. The computer screen presents relevant information associated with the event.

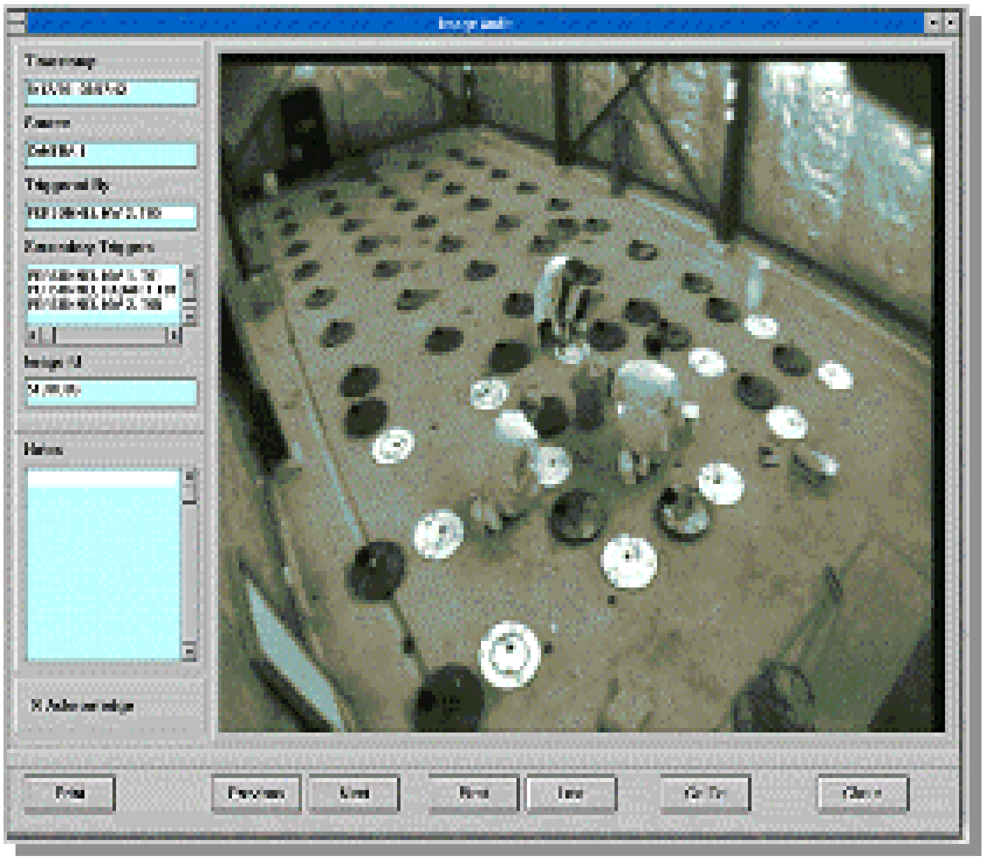

*Figure 7: Video Image Collected During Remote Monitoring*

The ability to collect information selectively makes remote monitoring less intrusive than human inspectors in many circumstances. Once installed, remote monitoring can supplement or substitute for on-site inspections. An advantage of using sensors is that they can operate continuously over long periods, which may be impractical for human observers. Of course, care must be taken to assure that a system reports credible data. A system must be designed and installed to minimize the potential for evasion. Examples of some monitoring functions and sensor types are contained in Figure 8.

Another method applicable to monitoring missiles is to focus observation activities at a "chokepoint". Chokepoints are relatively small locations that controlled items must physically traverse and thus present opportunities for monitoring. Examples of chokepoints relating to missiles are bridges and roads through mountain passes that TELs would have to cross during operational deployment or perimeter gates at production facilities or garrisons. Primary monitoring equipment applicable to chokepoints includes seismic, magnetic, and infrared sensors to detect and count traffic. Additional information can be collected by using strain cables (weight); multiple infrared break beams (profile and length); radiation detectors and X-ray equipment (characteristics of cargo), and cameras (number, shape, and color).

| Function | Sensor Type | Example | Purpose |
|---|---|---|---|
| ***Tracking Systems*** | Commercial Transport Tracking System | Portable, GPS-linked device determines/broadcasts location | Monitor location of patrol, vehicle, or cargo; record route taken |
| ***Seals*** | Passive Seals | Tape, wire, fiber-optic cable, plastic shrink-wrap, other means of sealing doors or containers | Reveal whether a sealed item or room has been opened since closure |
| | Active Seals | Seals linked to audible/visual alarm or radio transmitter | Provide immediate alert of tampering with sealed item |
| ***Access Control Systems*** | Alarmed Fences | Standard security fence with pressure-sensitive wires linked to alarm, camera or transmitter | Provide visible access barrier, intrusion warning |
| | Buried Fiber-Optic Cable | Pressure-sensitive buried cable linked to alarm, camera, or transmitter | Detect people or vehicles crossing a line of control |
| | Personal Entry Identifiers | Code locks, magnetic badges, palm scanners, other ID devices | Limit access to authorized people |
| ***Detectors*** | Metal Detectors | Walk-through and hand-held magnetic sensors | Locate concealed weapons or other metallic items |
| | Chemical Detectors | Detection of traces of specific chemicals on vehicles, people, or cargo | Locate concealed drugs, ammunition, or explosives |
| | Portable X-Ray Machines | Standard airport baggage viewers | Identify contents of bags and small boxes |
| ***Unattended Ground Sensors*** | Seismic, Magnetic, Acoustic Sensors | Transmitter activated by vibration, ferrous metal, or sound waves | Detect people, weapons, or vehicles |
| | Infrared and Microwave Break-Beam Devices | Alarm or transmitter activated when line-of-sight beam interrupted | Detect people or vehicles crossing a line of control |
| ***Aerial or Satellite Imagery*** | Visual Photography | Standard photography, variable resolution and quality | Provide video or still photography, real time or recorded |
| | Infrared, Radar, Multi-spectral Imagery | Infrared Camera<br>Synthetic Aperture Radar | Image through darkness, clouds, vegetation; detect objects, terrain not visible to the human eye |
| ***Tags*** | Bar Codes | Adhesive tape with readable bar code; bar code scanner | Identify individual pieces of equipment; facilitate inventory |
| | Reflective Particle Tag | Metallic particles suspended in polymer coating form unique pattern on equipment | Identify individual pieces of equipment |

*Figure 8: Examples of Monitoring Systems*

Perimeter monitoring detects and identifies controlled traffic crossing in or out of a defined area. The limiting factors on monitoring large areas using on-site sensors are the number and cost of the sensors required for effective coverage and the ability to integrate data from numerous sensors into a coherent report. One method for monitoring large areas is to divide it into smaller sectors using lines of sensors. Movement between the sectors can then be detected. Sensors used for monitoring boundaries include radar, infrared break-beams, and fences with sensors to detect climbing or cutting. Perimeter monitoring can be combined with chokepoint monitoring at a facility entrance to implement "portal-perimeter" monitoring. Figure 9 shows an example of continuous portal monitoring at the missile assembly plant in Votkinsk, Russia under the INF Treaty. In this monitoring system, traffic leaving the plant's sole gate was examined by a variety of sensors to determine whether a controlled item could be in the cargo. If the cargo appeared able to contain a treaty-controlled item, on-site inspectors examined it.


*Figure 9. Chokepoint, Monitoring Console and Display at the Votkinsk Facility*

### 4.3.2. Remote Sensing

Remote sensing is the collection of information where the sensor is a significant distance away from the object or activity of interest. It is generally viewed as less intrusive than on-site monitoring. Remote sensing includes satellite or aerial imaging; radar data collection; observation posts using cameras, radars, or human observers; electronic signal collection; and the collection of effluent samples (e.g., air or water) outside the boundary of the facility. A limitation on remote sensing is that it cannot monitor activity inside buildings or tunnels. Some important observables, such as the radiation emitted by nuclear warheads, are only detectable at distances of a few meters.

Although the cost of national satellites limits them to the wealthiest countries, the growth of the commercial satellite industry enables any country to purchase an image of virtually any location on the globe for a relatively low price. The number of commercial satellites and imagery products available has increased significantly in the last five years. Figure 10 shows an example of high-resolution imagery from the U.S. Quickbird commercial satellite that might have a potential role in monitoring missile-related activities.

Figure 10: 62 cm Resolution Image From the Quickbird Satellite

Aerial monitoring may be conducted cooperatively. The Open Skies Treaty entered into force in 2002 and is intended to provide transparency into military status among its signatories in Europe and North America. It permits a signatory to fly a jointly staffed aircraft over the territory of another signatory, subject to certain operational rules and using approved sensors (optical, thermal infrared, and imaging radar with defined resolutions). Hungary and Romania signed a simpler bilateral agreement to permit cooperative aerial overflight in 1991.

# 5. Approaches to Missile Control

The goal of missile nonproliferation can be pursued in a variety of ways:

1. Reducing the demand for missiles by decreasing the perception of national threats
2. Restricting the export of missiles and associated equipment
3. Restricting information describing missile technology
4. Limiting missile development activities such as flight or engine tests
5. Restricting the operational deployment of existing missile forces
6. Reducing existing missile forces by number and/or type.

## *5.1. Decreasing Threat Perceptions*

### 5.1.1. De-alerting

De-alerting measures are defined as "reversible actions taken to increase the time or effort required to launch a missile."[8] Nations retain their missiles and continue training, but operational impediments are intentionally put in place. These measures are designed to prevent accidents or unauthorized use and to slow the intentional use of a weapon system by requiring time to re-activate and/or re-deploy the system. A de-alerting agreement may require that the parties accept some degree of transparency about potentially sensitive military facilities. There are various levels of de-alertment. Actions can be declaratory or verified by periodic on-site inspection or remote monitoring. The following paragraphs summarize several de-alerting approaches (in order of increasing delay).

Missiles could be stored fully assembled rather than deployed operationally and ready for use. Further de-alerting could be achieved by removing critical missiles components. Components that have been removed could be co-located, stored in another building, or at a separate base. Liquid-fueled missiles could be stored unfueled, thus requiring the time-consuming process of fueling to take place before the missle can be launched.

The amount of delay could be increased by installing physical or electronic barriers to access at storage facilities. Such barriers would lengthen the process of deploying the missiles. Various approaches are technically feasible, but there are no precedents for their use in missile arms control:

- A massive block of concrete could be placed in front of the door to storage facility for warheads or missiles. The block would require the use of special equipment to be removed.
- Underground launch silo doors could be covered with earth-fill or a heavy object.
- Electronic timers could be employed to require a fixed time interval before opening or unlocking the door to a missile storage facility. Similar technologies are integrated into bank vault doors that cannot be opened outside of business hours. Electronic timers could also be

[8] Michael W. Edenburn et. al., "De-Alerting Strategic Ballistic Missiles," Cooperative Monitoring Center Occasional Paper/9, SAND98-0505/9 (Albuquerque, NM: Sandia National Laboratories, March 1999).

incorporated into the launching process to provide a time interval during which the launch could be canceled.

- An item could be attached to a missile or missile launcher that makes it inoperable without its being removed. Examples include a weight attached to a tail fin of a missile that prevents normal flight by changing its balance or a block (similar in principle to a bicycle lock) on the rail of the TEL that raises the missile to launch position.

The continued presence of agreed barriers can be verified by monitoring systems using sensors such as pressure switches, motion sensors, and/or cameras to detect removal. The status of electronic lock-out mechanisms could also be monitored to provide warning of a potential threat.

### 5.1.2. De-targeting

De-targeting is the process of entering harmless target coordinates into a missile guidance system. Examples include targeting broad ocean areas or uninhabited territory within one's own country. A precedent for de-targeting was established in January 1994 when US President Clinton and Russian President Yeltsin agreed in the Moscow Declaration to "direct the de-targeting of strategic nuclear missiles under their respective commands so that by not later than May 30, 1994, those missiles will not be targeted."[9] In practice, new target coordinates can be entered fairly quickly and the process is best applied to long-range and sophisticated missiles. Old missiles, such as the Scud, have unsophisticated guidance systems with few parameters to set for flight. While de-targeting is primarily a symbolic gesture and difficult to verify, as a unilateral measure it could provide value if there were concern about the potential for an accidental or unauthorized missile launch.

### 5.1.3. Self-Destruct Mechanisms

Self-destruct features are intended to permit manual or automatic destruction of a missile that is on an errant trajectory or that may have been launched unintentionally. There are no precedents for using these measures on operational missiles, but self-destruct commands have been used for safety purposes at the missile test ranges of several countries in response to missile malfunctions.[10] National militaries have been reluctant to accept this concept because of the potential for an adversary to activate the self-destruct function during a conflict.

### 5.1.4. Administrative and Technical Use-Control

The perceived threat posed by missile systems could be reduced if administrative and technical measures to control use were implemented. Use-control measures are procedures, hardware, or software that limit or restrict access to or use of a weapon system. They are intended to prevent external threats by unauthorized users and also control use by authorized personnel. Missile TELs do not typically incorporate use-control features, although US and Soviet ICBMs have such features. Cooperation in use-

[9] Text of Moscow Declaration by President Clinton and Russian President Yeltsin, Moscow, 14 January 1994. Internet: http://www.fas.org/nuke/control/detarget/docs/940114-321186.htm

[10] Michael W. Edenburn et al., "De-Alerting Strategic Ballistic Missiles."

control systems is unlikely due to classification issues, but unilateral implementation of use-control would reduce the likelihood of unauthorized use. If this implementation were made public, it could increase confidence in other countries that unauthorized elements within the government or non-government groups could not launch a missile.

The following are examples of use-control actions:

- Incorporate access control hardware into missile storage facilities as shown in Figure 11 (including missiles, warheads, TELs, and ancillary equipment such as fuel trucks)
- Implement a two-man rule for all launch procedures (i.e., require that two authorized individuals simultaneously enter commands into the control panel to operate the system)
- Implement a personnel reliability program for all missile crews and missile control headquarters
- Incorporate a dual key system to activate the launcher sequence. The unit commander and his deputy would each have a physical ("hard") key that must be turned in the control panel at a specific time to activate the control panel.
- Incorporate a hard key/soft key system to activate the launch sequence. The unit commander would turn a hard key as in the option above. The controlling headquarters would simultaneously transmit an encrypted numeric ("soft") key directly to the launcher. The unit commander would not know the soft key.

*Figure 11: Access Control Device Using Hand Geometry For Identification*

### 5.2. Restricting the Export of Missiles and Equipment

Because missile systems are not necessarily indigenous products, control of missile threats must address the commerce of missiles. Beginning in 1987, seven countries met to establish the Missile

Technology Control Regime (MTCR). At present 32 countries are participants. The MTCR sets guidelines for commerce in missile-related technologies and components.

The MTCR does not have provisions for information exchange and verification. Technologically based options to strengthen the MTCR include:

- A dynamic database administered by a secretariat would update declarations of exports and MTCR-related events as they occur.
- Declared items could be tagged as illustrated in Figure 12 to assure that their export was in accordance with the MTCR.
- A database system of chain-of-custody for exported missiles and missile components would serve to detect diversion and reinforce the use of identification tags described above. The system is similar in principle to the package tracking systems used by express mail companies.
- Seals could be applied to shipping and storage containers with MTCR-regulated items. This would indicate illicit diversion of exports and thus be a deterrent.


*Figure 12: Tags Installed By UN Inspectors on Controlled Missiles in Iraq*

### 5.3. Restricting Information Describing Missile Technology

Information describing missile technology can be easily contained in reports, books, tapes, computer disks, and compact disks. National systems of security and export control can address part of this risk to nonproliferation. However, preventing missile technology transfer when conducted by a state party is difficult to detect and impossible to stop with technological measures. The threat of economic and social sanctions by the rest of the international community can act as a deterrent.

### 5.4. Limiting Missile Development Activities

Actions to limit missile development usually focus on testing activities. Missile test limits are intended to make the development of new or significantly modified missiles more difficult. Systems that lack sufficient development and testing to be used reliably are unlikely to be assigned to operational units.

Flight tests of prototype missiles are the most important, but tests are also conducted on the ground. Ground testing can include static motor ignition, vibration, stress, and balance tests. Testing can be limited by the number, trajectory, and/or type of tests. For example, in the early 1990s Iraq was permitted to conduct static motor tests for short-range missiles under United Nations monitoring.

National technical means are used by many countries to observe missile testing activities at official and covert sites. Monitoring a cooperative agreement assumes, at a minimum, that test sites are declared. The following sections describe cooperative options to monitor missile tests.

### 5.4.1. Monitoring Flight Tests

The objective of monitoring a test missile's flight is to:

- Detect when a flight has occurred
- Confirm that the trajectory is not a threat
- Confirm the type of missile being tested (if this is limited)
- Determine the range of the test (if this is limited).

#### 5.4.1.1. Remote Sensing

Imagery from satellites or aircraft could detect preparations for a test flight, missiles on launchers, and post-launch effects such as burn marks. Imagery with resolutions of 50 cm or less would be needed for positive identification of the missile type. The observables associated with a test launch are transient and relatively small in physical size, so the spatial resolution of commercial satellite imagery and the fixed revisit times limit its effectiveness. Imagery from aircraft can have greater resolution and flexibility in scheduling but would require continuous overflights to detect undeclared tests. Random, short-notice overflights could reduce the number of flights needed because a country considering evasive testing would not know the schedule. Optical sensors on both commercial satellites and aircraft are adversely affected by weather conditions, but radar can be used during periods of cloudiness or darkness.

Ground-based radar can detect test missiles rise as they rise above the launch site. Placing radars to detect all launches can be difficult if the launch sites are located far in the interior of the country or in mountainous terrain. Some sophisticated military radars can overcome the line-of-sight problem by using very large antennas that can send and receive signals over the horizon at ranges of several thousand kilometers. A possible cooperative approach is to place a small, autonomously operated radar at the test site. This system would detect and provide the initial trajectory for launches. Another option is to include a beacon on the test missile that announces the missile's launch and assists tracking by radars located outside the country. This beacon could be the same as those used in commercial aircraft to enable tracking by civilian flight control radars that provide nearly complete, worldwide coverage. There is no precedent for these types of monitoring for missile tests.

A test missile normally transmits data to its ground station for later analysis. Under the START treaties, telemetry data from missile test launches may not be encrypted. The effect of this agreement is to share test data and provide real-time information about the trajectory. Cooperative parties might even define test standards such as frequencies for jointly receiving telemetry.

#### 5.4.1.2. On-site Observers

On-site observation can confirm a test has occurred. If the test is declared in advance, observers could be invited to observe test preparations and the launch. A continuous on-site presence would be necessary if there were concerns about undeclared launches. A less intrusive alternative would be to permit a defined number of challenge inspections.

#### 5.4.1.3. On-site Remote Monitoring

Remote monitoring using sensors installed at a launch site could confirm launches with less intrusiveness than human observers. Video cameras could be used to continuously observe certain locations at the test site. An alternative would be to use infrared and acoustic sensors to detect a launch, report the event, and activate a video camera.

### 5.4.2. Monitoring Ground-based Tests

The objective of monitoring a ground test is to:

- Detect when a test has occurred
- Confirm the type of missile component being tested (if this is limited)
- Determine the type of test being conducted (if this is limited).

#### 5.4.2.1. Remote Sensing

Given that ground-based tests are smaller than complete missile tests and may be conducted inside buildings, remote sensing has a limited role. Some test preparations or activities, such as static motor tests, may be observable.

#### 5.4.2.2. On-site Observers

On-site observers can confirm declared tests have occurred but their presence is intrusive, because they are located close to facility operations. They would not be able to detect and identify undeclared tests unless they were present continuously and had free and complete access to the test site.

#### 5.4.2.3. Remote Monitoring

Remote monitoring can provide continuous observation with less intrusiveness than human observers. The active area of sensors and the data they collect can be defined. An example of potential remote monitoring is the use of visual and thermal video to record the duration of a rocket motor test and the size of the plume. From this information, the size of missiles and the range/payload combinations the rocket motor could propel can be estimated. Figure 13 shows an example of on-site sensors monitoring the interior of a storage vault.

*Figure 13. An Example of Remote Monitoring Equipment in a Storage Vault*

## 5.5. Restricting Operational Deployment of Existing Missile Forces

### 5.5.1. Zones

Restricting deployment of missiles from specific geographic locations moves them away from preferred launching points, so that likely targets are outside of their range. An alternative approach is to restrict mobile missiles to their garrisons. Without verification, an agreement to restrict geographic deployment is ineffective. However, monitoring could increase instability if it provides information that enables targeting of missile forces. Therefore monitoring must provide information that is geographically and temporally specific enough to provide assurance that the parties are complying with the agreement, yet not so specific that it creates vulnerabilities.

#### 5.5.1.1. Remote Sensing

If missiles were located in fixed sites, site closure could be monitored by imagery from commercial satellites or aircraft. Missiles are large enough to be easily identifiable on external launchers. Silo doors could be opened during imaging to confirm that no missile is present. Facilities with horizontal doors, such as tunnels or storage buildings, do not offer a line-of-site for imaging and their closure would need to be verified by on-site inspection.

Mobile missile launchers might be monitored if imagery were collected cooperatively. The approach is based on restricting missiles to a geographic zone with the option for the parties to call a "census" of declared missiles. The census would require the missile launchers to move to positions within the zone where they could be photographed. The launchers would have several hours to move into position. At the agreed time, a commercial satellite or aircraft would image the entire zone. After imaging the launchers would disperse. There is a time lag from the when the image is taken to the when it is available for analysis. This results from the time required to download the data from a satellite to a ground station or for the aircraft to return to base and its film to be processed. This lag is used to prevent the missile launchers from being targeted as a result of the imaging. In practice, it means that the declared missiles can move no farther from the zone than the period available to return if a census is called. Care must be taken to distinguish between decoys and actual launchers in an image.

#### 5.5.1.2. On-Site Observation

Observers might enter the non-deployment zone periodically to determine if any missile systems are present. This is an intrusiveness process that is largely ineffective unless the non-deployment zone is small or observers are present continually.

#### 5.5.1.3. Remote Monitoring

If the zone is geographically restricted from the rest of the country by mountains or some other terrain feature, chokepoint monitoring could be established on routes into the zone. If it is possible to re-enter the zone on other routes, such a system would be ineffective.

A new monitoring concept is to apply active tags to missiles or TELs that report to the other party if they have entered a non-deployment zone. The tag would be based on geographic information system (GIS) software and GPS data. The shape and coordinates of the non-deployment zone are entered into the GIS software. The tag receives signals from GPS satellites, determines its position, and compares it to the boundaries of the zone using the GIS. If the tag is within the zone, it reports that fact using a cellular or satellite telephone modem. The report does not include the specific location of the tag and thus does not create vulnerability. The tag would include features to detect tampering. During operation, the tag would report its state-of-health periodically, including whether it had been removed or opened. Failure to report would constitute an incident. Interception of the tag's cellular or satellite telephone signal does not provide geographic information that is detailed enough for targeting purposes unless intercepted very close to the point of transmission.

### 5.5.2. Capability

Setting limits on capability bounds threats and could include such parameters as size, range, payload capacity, or multiple warheads. As in the INF treaty, capability limits could also seek to eliminate or prevent development or deployment of an entire category of missile systems such as ship or submarine-launched missiles. Verification would require intrusive inspections to confirm the absence of all banned systems. Depending on the agreement, remote monitoring of the exterior entries or interior production operations at a facility could verify that prohibited items are not in production.

## *5.6. Reducing Existing Missile Forces*

### 5.6.1. Quantity Limits

Setting total quantity and production limits for missiles would limit their threat but requires significant intrusiveness to verify. In this case the number of weapons systems of a particular type that exist would be declared, then a baseline inspection conducted to confirm the declaration. Tagging controlled items might be needed to ensure the accuracy of the count. Any items discovered subsequently without tags would be in violation of the agreement. If quantity limits require reductions in the existing inventories of missiles, destruction would be monitored. Past treaties have used cutting, exploding, or even launching missiles to reduce inventories.

Production monitoring and inspections to verify limits can be implemented using many of the techniques previously described. Under the INF Treaty, the US and USSR maintained monitoring equipment and personnel at missile production sites in each country for thirteen years. Shipments exiting production facilities were monitored. Although production areas inside the facilities were not inspected, inspections were conducted to verify that missiles had been destroyed. Figure 14 shows an inspection to verify missile destruction under the INF Treaty.

*Figure 14: INF Treaty elimination inspection of a US cruise missile*

# 6. Conclusions

The concepts described in this paper represent a wide range of possibilities for missile control. However, political will and other factors do not make all of these options equally attractive in the near term. Figure 15 summarizes the ideas presented and a sequence in which they might be implemented. The first step must be a willingness to address the issues. Establishing a dialogue on missile threats is essential. Initially, the dialogue could be limited in scope with more topics addressed as experience and conditions permit.

| Near Term | Mid Term | Long Term |
|---|---|---|
| • Begin missile dialogue<br>• Establish or expand hotline and data sharing communications infrastructure<br>• Start and formalize missile launch notifications<br>• Maintain unilateral non-deployed missile status including non-deployment areas<br>• Seek means for minimizing misinterpretation, such as trajectory of test launches | • Set missile capability limits<br>• Formalize limits on missile trade<br>• Implement and monitor launch barriers<br>• Establish and monitor missile non-deployment zones<br>• Provide declarations of missile force structures and quantities<br>• Define and conduct missile monitoring experiments | • Establish and monitor missile quantity limits or elimination regimes<br>• Monitor system or component removal and missile de-alert status<br>• Verify missile use control<br>• Formally establish or participate in missile control regimes |

*Figure 15: Missile Threat Reduction Time Frames*

# 7. Distribution

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