The missile regime: verification, test bans and free zones

Over sixty years after the introduction of nuclear weapons and ballistic missiles in the Second World War, the international strategic environment is becoming increasingly complex and competitive. The Revolution in Military Affairs penetrates multiple dimensions of national and international security. The arms race extends from nanospace to outer space, transcending national borders.

Nuclear weapons and missiles, which played a central role during the Cold War, have not lost their prominence: strong political forces maintain that nuclear deterrence remains a cornerstone of national security for the foreseeable future, despite a growing movement to eliminate nuclear arsenals. In 2002, the United States asserted that its nuclear weapons would continue to play a “critical role” because they possess “unique properties”.¹

However, without an appropriate delivery capability, the military utility of nuclear weapons is limited. Missiles appear attractive as they are much easier to operate than manned bomber aircraft and do not expose an attacker’s personnel to direct risk.² The lack of legal structures or taboos against the development, testing and maintenance of missiles creates a conducive environment for their testing. Thus, these complex systems are tested with increasing frequency and are increasingly threatening international stability.

To deal with this threat, the ultimate goal for the authors of this paper is the Zero Ballistic Missile (ZBM) regime proposed by the Federation of American Scientists in the early 1990s.³ However, as a starting point we propose that states notify each other in advance of missile flight tests in order to reduce tensions and potential for conflicts. This would be a first step toward a gradual missile flight test ban as a part of a zone free of weapons of mass destruction (WMD).

In theory, an advance notification of a missile flight test is realizable and its verification is both technically feasible and financially affordable. Missile testing can be easily monitored from remote sites on the ground, in the air or from space. The non-deployment of missiles can be verified with airborne visual inspection or from space.⁴ Moreover, the verification process would be a valuable confidence-building measure, and could be particularly beneficial to regions where tensions run high, such as South Asia and the Middle East. The Peace Research Institute Frankfurt has set up a Multilateral Study Group on the Establishment of a Missile-Free Zone in the Middle East (MSG). The MSG, academic and theoretical in nature, brings together experts from the Middle East, China, Europe, the Russian Federation and the United States. It is an attempt to explore a regional effort to control delivery systems as well as to examine the possibility of banning their testing as part of the overall effort to establish a WMD-free zone in the Middle East.
Moving toward a flight test ban: evolution of an idea

To avoid a new arms race on a regional, or even global, scale, there have been a number of suggestions for more comprehensive arms control approaches with regard to missiles. While the concept has some political appeal, it is yet to prove realizable.

The idea isn’t new: one can date it back to the 1950s, when the concept of a flight test ban was explored in order to get international disarmament negotiations under way. France, the United Kingdom, and later the United States perceived this as an ideal opportunity to curb the nascent Soviet missile programme. However, the discussions fell through for reasons beyond the scope of this paper. The idea was revisited in 1986, when Ronald Reagan and Mikhail Gorbachev met at the Reykjavik Summit to discuss perhaps the most far-reaching proposal to eliminate ballistic missiles. Unfortunately, these negotiations collapsed due to differences about President Reagan’s Strategic Defense Initiative (SDI, also known as Star Wars).5

In 1987, the Missile Technology Control Regime (MTCR) was initiated by the Group of Seven (Canada, France, West Germany, Italy, Japan, United Kingdom and United States). The MTCR is a voluntary and informal agreement that aims to prohibit the transfer and spread of ballistic and cruise missile technologies to non-member states.6 The regime’s membership expanded to 29 in 1997 and by the end of 2004 it had 34 member states. Under the MTCR, states defined a nuclear-capable missile as one able to deliver a 500kg or greater payload to a distance of 300km or more. These parameters corresponded to the perceived minimum weight of a nuclear warhead, and to the strategic distances in the most compact theatres where nuclear-armed missiles might be used. In 1992 the scope of the MTCR was expanded to include unmanned aerial vehicles for the delivery of WMD, making the payload and range thresholds less rigid.

The MTCR has played a significant role in constraining horizontal proliferation of long-range ballistic missiles, especially in the developing world. This could be attributed to the regime having increased the financial costs of proliferation.7 Complete ballistic missile systems as well as key components, subsystems and manufacturing technology have become less available, as has the technical expertise vital to the development and manufacture of ballistic missiles. The regime’s expansion has also been instrumental in promoting the concept of a missile non-proliferation “norm”. This norm has helped drive up the political costs of proliferating for those countries determined to acquire a ballistic missile capability or enhance existing systems. In 2002, the MTCR was supplemented by The Hague Code of Conduct against Ballistic Missile Proliferation (HCOC), which calls for restraint in the proliferation of unmanned delivery systems, and has 130 members to date.8

Despite some success in delaying missile programmes and building a basis of support, the MTCR has some fundamental drawbacks that limit its effectiveness.9 For example, the MTCR’s approach of technology denial is a long-term solution to proliferation concerns. It does not restrain existing arsenals or programmes. A new alternative would be to follow a path toward missile disarmament following the proposals of the 1986 Reykjavik summit.10 Curbing missile development by a flight test ban—including development by the nuclear-weapon states and others with advanced missile programmes—would be an important step.

Flight testing is an integral part of the missile development process. Most countries that have or seek to develop missiles with accurate inertial guidance, solid fuel and multi-staging, undertake numerous flight tests to ensure confidence. While the need to test can be reduced with advances in computer simulations, improvements in static firings of rocket motors, and the transfer of knowledge from space launches, the history of missile development demonstrates that new missiles and new technologies that have performed well in computer simulation and ground testing can reveal unpredicted fatal defects in flight testing. For example, there were reports that the United States’
MX missile inertial guidance system performed brilliantly in early development tests, but its accuracy fell off when the production team took over. Even states with existing ballistic missile arsenals would probably argue that flight testing of existing systems is essential to preserve their reliability. Thus, if missile flight testing were banned, the loss would be similar to the loss of confidence in the reliability of nuclear weapons that is expected from the Comprehensive Nuclear-Test-Ban Treaty (CTBT), and should reduce the likelihood of a pre-emptive first strike. By notifying each other in advance of a flight test and subsequently verifying the test, states could build the requisite confidence to negotiate a test freeze, and could lay the foundation for negotiating a missile flight test ban.

Affordable and verifiable

Compliance with missile test notification would be relatively easy to verify technically, provided that the remote sensing of missile launches is supplemented by provisions to minimize the risk of the conversion of space launchers into ballistic missiles. As the then CIA Director William Webster acknowledged in May 1989, “The status of missile development programs is less difficult to track than nuclear weapons development. New missile systems must be tested thoroughly and in the open...” The existing national technical means of the most technologically capable states are already able to detect and track, for example, ballistic missile launches, trajectory and telemetry. US early warning satellites can track missile launches around the world. Detecting test preparations of mobile missile systems may pose a problem, but the actual flight tests would still be detectable. In addition, an array of ground-based radar systems would provide reliable launch detection, target acquisition and tracking. Over-the-horizon and sea-based radar could extend coverage into areas difficult to reach for ground-based radar.

The role of technology should not be underestimated in verification. Technology helps in systematically collecting, analysing, storing and rapidly disseminating information. Technology can operate continuously and at a constant level compared to human inspectors. Technology can also be designed to detect treaty-relevant information only. For example, in the 1987 Intermediate-Range Nuclear Forces (INF) treaty between the Soviet Union and the United States, it was permitted to X-ray the missile canister to determine the type of missile; however, the resolution of the X-ray was constrained so that other sensitive information was not revealed. Space-based and aerial technologies are common methods of verification. However, both these technologies suffer from significant disadvantages.

The infrasound sensor component of the International Monitoring System (IMS) of the Comprehensive Nuclear-Test-Ban Treaty Organization Preparatory Commission could aid in detecting and confirming a missile launch. The IMS is a network of monitoring sensors set up to detect and provide evidence of nuclear explosions to CTBT states parties for the purposes of treaty verification. Infrasound, part of the acoustic spectrum lying below the range of human hearing (i.e. approximately 20–0.001Hz), is of particular interest for the monitoring of a number of man-made and natural phenomena. This is primarily due to the lack of significant attenuation at these frequencies in Earth’s atmosphere, allowing acoustic waves to be observed even after travelling thousands of kilometres.

As a typical rocket infrasound signal is in the 0.1–1Hz frequency range it will be possible to detect missile flight launches in the acoustic far field, far from the launch site. The detection of infrasound from rockets primarily depends on three different factors:

- the local noise conditions at the site of the receiver;
- the propagation conditions between the source and the receiver; and
- source characterization.
We can investigate the potential of the IMS infrasound’s network to detect rocket launches using an instance of a detection at Aktyubinsk (shown in Figure 1). The detection observed is that of the Zenith rocket, which was launched on 29 June 2007 from Baikonur Cosmodrome at 1000 UTC (Universal Coordinated Time). The sound waves arrive at the sensor at approximately 1032 UTC.

Using a minimum of three microphones, the spacing of which depends upon the frequency characteristics of the waves of interest, the individual channels of the array are cross-correlated and spatially transformed over a finite window time in order to provide a direction from which the wave energy in the window arrives at the receiving array. On performing this procedure repeatedly over the length of a time series that contains a signal, the back azimuth as well as the wave velocity can be computed.

Based on openly available data of detections at Aktyubinsk and other stations, an empirical relation of the maximum distance at which a rocket can be detected versus the class of the rocket has been derived by P. Brown et al.\textsuperscript{20} This relation is given as follows:

$$1.3\log(R) = 2.759 + \log(NP),$$

where $R$ is the maximum range in kilometres, and $NP$ is the noise power of rockets (the total amount of acoustical energy radiated per unit of time).

This relation is used to determine the maximum horizontal detection range of rockets. Table 1 lists the maximum detection range of certain rockets currently in military arsenals.

**Table 1. Detection ranges for an infrasound station for select missiles**

<table>
<thead>
<tr>
<th>Rocket name</th>
<th>Liftoff thrust (kN)</th>
<th>Maximum horizontal distance at which the rocket launch can be detected (km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proton</td>
<td>10,470</td>
<td>6,300</td>
</tr>
<tr>
<td>Ariane 5</td>
<td>6,470</td>
<td>4,500</td>
</tr>
<tr>
<td>Agni II</td>
<td>503</td>
<td>675</td>
</tr>
<tr>
<td>Scud-B</td>
<td>93</td>
<td>130</td>
</tr>
</tbody>
</table>

As monetary aspects play a crucial role in any verification agreement, having a verification system already established might help reduce costs. In this instance, it may very well reduce capital outlay. A design criterion of less than 0.1Hz is typical for all IMS infrasound stations, and this would be more than adequate for missile launch detection: rocket signals are prominent at 0.1–1Hz. The mean spacing between IMS stations is 2,500km on land and 4,500km in the oceans, which, referring to Table 1, would be sufficient to detect long-range missiles.

Were an independent verification system to be established to detect missile flight tests, the arrays could be smaller (baseline of 500m between sensors) than a typical IMS infrasound array as it would not need to detect signals at such low frequencies. A typical IMS infrasound array costs approximately US$ 200,000. This is primarily due to larger baselines and the inclusion of equipment to ensure that the data is not tampered with. The cost of an array purely for missile flight test detection would be approximately US$ 100,000, as shown in Table 2. The sum does not include basic infrastructure such as buildings, communications, and the empty and isolated land required to site the equipment, which could easily add up to another 50% of the overall cost. Operating costs should also be taken into account, and so must personnel.\textsuperscript{21}
Figure 1. Infrasound signal from Zenith rocket launch recorded at Aktyubinsk array (I31KZ).

Note: (a) The observed back azimuths (from the source to the receiver) seem to be arriving from between 135 and 139 degrees. The arrival velocities of the waves are between 0.33 and 0.37km/s. This is characteristic of infrasound velocities; (b) Radar plot showing the directions from which the signal originates; (c) Trajectory of the rocket, plotted using freely available software, and indicating the I31KZ sensor at Aktyubinsk as well as the launch pad at Baikonur Cosmodrome.
Building confidence

Finally, verification of flight tests using sensors such as the ones suggested here may also contribute positively to confidence building, thus constituting a preliminary step toward a possible flight test freeze, then ban. For example, India and Pakistan signed an agreement on 3 October 2005 to notify each other at least 72 hours in advance of a ballistic missile flight test. The two states also agreed not to allow trajectories of tested missiles to approach or land close either to their accepted borders or the Line of Control, the ceasefire line running through the disputed region of Kashmir. They pledged not to allow missiles being tested to fly closer than 40km from these boundaries or land less than 70km away. Verifying such missile tests with infrasonic sensors located on either side of the border will provide both countries with an opportunity to work together, to improve their knowledge of the technology, and to enhance mutual cooperation.

Missile test freeze in the Middle East

There is considerable literature on creating a nuclear-weapon-free zone (NWFZ) or WMD-free zone in the Middle East. Egyptian President Hosni Mubarak initiated the call for establishment of a WMD-free zone in April 1990. His proposal had three main components.

- The prohibition of all weapons of mass destruction—nuclear, chemical and biological—in all states of the Middle East.
- All states in the region should provide assurances toward the full implementation of this goal, in an equal and reciprocal manner to fulfil this end.
- Establishment of proper verification measures and modalities to ensure the compliance of all states of the region without exception.22

This was soon followed by a report of the UN Secretary-General on the “Establishment of a Nuclear-Weapon-Free Zone in the Region of the Middle East”.21 This proposal also suggested that a freeze on additional deployments of ballistic missiles could ease tensions in the region. The authors of the report said, “As a starting point for discussions, it would be desirable to consider a complete suspension by all States in the region of domestic production and of imports of missiles beyond a certain range.”24 The authors of the UN report admitted that small-scale violations of the production

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Table 2. Itemized cost for a 500m baseline infrasound array

<table>
<thead>
<tr>
<th>Item</th>
<th>Unit cost (US$)</th>
<th>Quantity</th>
<th>Total cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chaparral 2.5 MB vault</td>
<td>3,900</td>
<td>4</td>
<td>15,600</td>
</tr>
<tr>
<td>Soaker hose</td>
<td>15</td>
<td>48</td>
<td>720</td>
</tr>
<tr>
<td>Nanometric digitizer</td>
<td>10,000</td>
<td>4</td>
<td>40,000</td>
</tr>
<tr>
<td>GPS antenna</td>
<td>150</td>
<td>4</td>
<td>600</td>
</tr>
<tr>
<td>MB vault</td>
<td>3,000</td>
<td>4</td>
<td>12,000</td>
</tr>
<tr>
<td>Teck cable</td>
<td>13.5</td>
<td>2,500</td>
<td>33,750</td>
</tr>
<tr>
<td>DC power supply</td>
<td>300</td>
<td>1</td>
<td>300</td>
</tr>
<tr>
<td>UPS battery backup</td>
<td>2,500</td>
<td>1</td>
<td>2,500</td>
</tr>
<tr>
<td>Terminal server</td>
<td>3,000</td>
<td>1</td>
<td>3,000</td>
</tr>
<tr>
<td>Communication modem</td>
<td>1,000</td>
<td>4</td>
<td>4,000</td>
</tr>
<tr>
<td>Computer system</td>
<td>3,000</td>
<td>1</td>
<td>3,000</td>
</tr>
<tr>
<td>Software</td>
<td>15,000</td>
<td>1</td>
<td>15,000</td>
</tr>
<tr>
<td><strong>Net total</strong></td>
<td></td>
<td></td>
<td><strong>130,470</strong></td>
</tr>
</tbody>
</table>
and import freeze may occur, but argued that even a relatively simple verification scheme would be enough to detect substantial violations that could be considered militarily significant.

In May 1991 US President George Bush announced a Middle East arms control initiative that included a “freeze on the acquisition, production, and testing of surface-to-surface missiles by states in the region”. However, the proposal failed to gain traction, and the international arms industry continued to manufacture and sell arms to states in the region, including surface-to-surface missiles.

In 1995, the Non-Proliferation Treaty Review and Extension Conference agreed a special resolution on the Middle East, to which the 2000 Non-Proliferation Treaty Review Conference re-confirmed its commitment. The resolution focuses on achieving the following objectives.

- The establishment of a nuclear weapon-weapon-free zone in the Middle East.
- The accession to the NPT by states in the region that have not yet done so.
- The placement of all nuclear facilities in the Middle East under full-scope IAEA safeguards.

The establishment of an NWFZ in the Middle East would be a first step toward establishing an effectively verifiable NWFZ, and then a zone free of all WMD and their delivery systems. These, however, focus on banning the ordnance to be carried by missile delivery systems, not the delivery systems themselves.

Although there exists a range of literature on a WMD-free zone or a NWFZ in the Middle East, including studies recently published in the region, there is currently no specific literature on a missile-free zone in the Middle East. It is clear, however, from the proposals relating to a WMD- or nuclear-weapon-free zone, that many see a link between missile control and the creation of such a zone in the Middle East. One analyst has suggested that it might be possible to draw precedents from the INF Treaty for the Middle East in terms of verifying a missile ban or freeze as a step toward a WMD-free zone. The INF Treaty eliminated all intermediate-range missiles, defined as those having ranges between 1,000 and 5,500km, and shorter-range systems, defined having ranges between 500 and 1,000km. Only ballistic and cruise missiles fired from ground launchers were included. A revised, tailored regional INF agreement would have the advantage of already having been adhered to in practice.

**The road ahead**

If we are to successfully achieve a missile flight test ban, it is important to recognize the centrality of the issue of trust. Mutual trust is key in international relations and a vital ingredient in preventing the stalling of disarmament efforts. Here we define trust as the ability to form a basis for constructive dialogue, to form a medium for cross-cultural and cross-regional exchange, reaching out beyond comfort zones, building bridges and increasing intercultural tolerance. The definition of trust could also be extended to issues such as building mutual interests and respect for differences.

There must be candid conversation and constructive dialogue on nuclear disarmament: conversations should be held more frequently and all relevant opportunities for such conversations must be tapped. Members of civil society must be invited: in raising awareness on small arms, cluster munitions and on the need for a comprehensive nuclear test ban, non-governmental organizations (NGOs) have forged an action partnership with governments to achieve change that we are only beginning to see the consequences of. NGOs can also help in breaking the barriers between governments, they can lay the foundation for formal talks by enabling, organizing, sponsoring and conducting informal means of exchange. Gender perspectives can affect the way society views nuclear weapons and pave the way for them to be devalued and abolished—and the same applies...
to missile freeze and eventual destruction. As international efforts toward total nuclear disarmament
gather momentum with initiatives such as missile-free zones, the work of NGOs, and of men and
women around the world, must be acknowledged and given its due importance: everyone has a role
to play.

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the 2009 Carnegie International Nonproliferation Conference on “The Nuclear Order—Build or
Break”, held in Washington, DC, 6–7 April 2009.

Notes

6. The MTCR’s documents are available on its web site, <www.mtcr.info>.
8. The Hague Code of Conduct against Ballistic Missile Proliferation, signed November 2002 at The Hague. Austria serves as Immediate Central Contact (Executive Secretariat). See also UN General Assembly resolution 63/64 of 2 December 2008, UN document A/RES/63/64, 12 January 2009.
12. The CTBT has not yet entered into force, but a de facto moratorium on testing has existed since the treaty was opened for signature in 1996 (with several notable exceptions).
16. Ibid.

20. Ibid.

21. Ibid.


24. Ibid., paragraph 166.


29. See, for example, Sameh Aboul-Enein, 2009, “Creating a WMD Free Zone in the Middle East and Relevant Agreements”, *Al-Siyassa Al-Dawliya* (Egypt’s main political quarterly), no. 177, July.


32. Ibid.
