



www.sassu.org.uk

MARCH 2008

RESEARCH REPORT

08

**Preventing Ballistic Missile Proliferation
Through Flight Test Bans:
A Look at Verification Technologies**

By Bharath Gopaldaswamy - Series Editor: Maria Sultan

South Asian Strategic Stability Institute

Aims and Objectives

The South Asian Strategic Stability Institute (SASSI) is an autonomous, non-profit research organisation based on public-private partnership. It is devoted to providing an in-depth understanding and objective analysis of strategic stability in South Asia.

SASSI aims at making a leading contribution to regional and international academic and policy-orientated research discourses about South Asian security. Its work is focused on strategic stability in South Asia and thus on the emergent nuclear relationship which is at the heart of that stability.

However, SASSI's remit goes beyond nuclear stability to include the wider issues of chemical and biological weapons, conventional force balance, nuclear export control system, Pakistan's strategic culture, safety and security of Pakistan's nuclear programme, civil-military relations, social and political stability, religious extremism and the disputed territory of Kashmir, which inform the nature of security and stability in the South Asian security complex and thus impact on the nuclear relationship.

SASSI also conducts regular meetings and seminars of renowned academicians, policymakers and researchers, so creating an intellectual environment. It is establishing close liaison with similar institutes at the national and international level.

The South Asian Strategic Stability Institute aims at making a leading contribution about the South Asian security problematic. The institute focuses primarily on the nuclear and strategic stability debate in South Asia. The work and the studies carried out by SASSI are

intended to bring together various schools of thought ranging from the social and natural sciences as well as the policymakers, journalists and academia.

SASSI seeks to encourage innovation in thinking about these issues and in particular welcomes young scholars and the application of new ideas in peace and security thinking to the South Asian security problematic. To meet this challenge SASSI's main objectives are:

- Engage the academic and policy communities in serious debate about the promotion of strategic stability in South Asia;
- Promote innovative ideas to reduce tension and build trust and cooperation in the area of weapons of mass destruction (WMD);
- Contribute to academic and policy processes for establishing an arms control regime for South Asia;
- Facilitate South Asian scholars in the development of security research capacity in the field of WMD;
- Provide an independent and neutral platform on which South Asian scholars and other interested parties can meet to engage with South Asian strategic stability issues;
- To network and cooperate with individuals and organisations across the world with shared objectives.

The institute has gained recognition, prestige and credibility in a surprisingly short span of time. It is dedicated to the ideals of knowledge and learning. SASSI aims at broadening the mental horizons of the people inhabiting the South Asian region and the world and promoting among them a better understanding of each other's problems.



Copyright © South Asian Strategic Stability Institute Ltd, 2008

Production and Design: Nick Robson

Published by: South Asian Strategic Stability Institute (SASSI)

The views expressed in this report are those of the author and do not necessarily represent the views of the South Asian Strategic Stability Institute. All SASSI publications are peer reviewed.

**Preventing Ballistic Missile
Proliferation Through Flight Test Bans:
A Look At Verification Technologies**

Bharath Gopaldaswamy

SASSI Research Report 8

March 2008

Published by

**South Asian Strategic Stability Institute (SASSI),
36 Alie Street, London, E1 8DA**

© South Asian Strategic Stability Institute 2008

CONTENTS

Abstract.....	1
Introduction.....	2
Current Status of Ballistic Missile Arsenal.....	2
International Controls on Missile Proliferation.....	3
Flight Test Bans.....	4
Verification.....	5
Verification Technologies.....	6
Conclusion.....	10
Appendix A.....	10



Preventing Ballistic Missile Proliferation through Flight Test Bans: A look at verification technologies

Bharath Gopaldaswamy

Abstract

The proliferation of ballistic missiles has long been a major international security concern. Ballistic missiles enable states to rapidly deliver weapons of mass destruction (WMDs) over vast distances, and missile proliferation therefore exacerbates the WMD threat. The existing measures such as the Missile Technology Control Regime (MTCR) and the Hague Code of Conduct have had very little effect in containing missile proliferation. This paper discusses flight test ban as a possible alternative in curbing missile proliferation. Although flight tests may not be necessary for countries, which possess Scud type technology, flight tests are still necessary for countries, which intend to develop long-range systems. Verification technologies such as remote sensing and infrasound monitoring have been discussed. One particular concern on the missile non-proliferation agenda is that of satellite launch vehicles (SLVs) and it has also been addressed.



Introduction

The introduction of missiles as a key delivery system for nuclear, biological and chemical as well conventional weapons has exponentially increased the destructive potential of militaries worldwide. One reason for this is the relative difficulty in acquiring anti-missile systems both because of technological and financial constraints. A workable, fool-proof ballistic missile defence system covering the entire geographical area of a country is yet to be put in place. Moreover, it is hard to defend against non-ballistic missiles even for a country like the US. In the 1991 Gulf War, the sporadic Scud campaign by Iraq caused the commanders of the allied forces to devote significant resources to detecting, tracking and attacking the missile launchers, albeit with marginal success.

The international concern about missile proliferation has increased substantially after the Cold War. Missiles present a great amount of security problems due to their long range and their ability to carry conventional and nuclear payloads. Missile non-proliferation arrangements have a lot in common with nuclear non-proliferation efforts. Because the same technologies can be used both for space endeavours as well as developing missiles, halting the proliferation of missile technologies has been a tricky issue. Thus, the major underlying concern regarding missile proliferation is the threat of deliberate or unauthorised diversion of dual-use technologies, equipment and expertise to military application.

Verification and safeguards mechanism is an issue missile non-proliferation experts have been trying to answer for a number of years. Although it is quite unlikely that in the near future it will become possible to develop mechanisms that would make assistance to SLV programmes absolutely missile proliferation-safe, it is at least worth looking at technologies, which can assist in monitoring these proliferation issues in greater depth. It must also be

noted that the efficiency of the verification depends on the stage in the missile life-cycle that is to be controlled. Limits on research and development (R&D) would impede the growth of indigenous missile programme; dual use is the main problem that must be overcome. With space cooperation and conversion of military R&D facilities plus inspection of suspected sites, verification could exclude the most relevant developments but would require extensive procedures likely to interfere with legitimate civilian R&D.

This paper proposes the prevention of ballistic missile proliferation through flight-test bans. With the assistance of remote sensing of ground-based test facilities, infrastructures can be observed from air and space. Thermal detection of missile plumes also aid in the verification of static tests. And on-site inspection can be carried out to confirm the tests. Since ballistic missile launches can be easily detected by early warning satellites and ground- or air-based radars, a ballistic missile flight-test ban would be rather easy to verify by remote sensing and the interception of telemetry data. Potential launch facilities could also be verified by non-destructive measurements and tests.

This paper focuses on generic strategies and techniques that would aid verification of missile proliferation. However, it should be noted that the effectiveness of these technologies depends on a complex combination of political, technical and operational forces, which cannot be accurately determined.

Current Status of Ballistic Missile Arsenal

There are various definitions of missile range categories. In this analysis, the classification categories are obtained from Centre for Defence and International Studies (UK):¹

Battlefield Short Range Ballistic Missile

¹Centre for Defence and International Studies (UK) (www.cdiss.org/bmrange.htm).

(BSRBM): Up to 150 KM

Short-Range Ballistic Missile (SRBM): 150-800 KM

Medium-Range Ballistic Missile (MRBM): 800-2,400 KM

Intermediate-Range Ballistic Missile (IRBM): 2,400-5,500 KM

Intercontinental Ballistic Missile (ICBM): Over 5,500 KM

Currently, short-range ballistic missiles are possessed by several countries. A few of the countries have medium- and intermediate-range while only a handful of them possess powerful intercontinental missiles. Around 17 countries in the world today have only short-range ballistic missiles deployed. Around six countries have short- and medium-range ballistic missiles deployed and only five countries have deployed long-range ballistic missiles as of 2007.²

Six countries – India, Iran, North Korea, Pakistan, Israel and China – have tested and built IRBMs. Iran's Shahab-3 and Pakistan's Ghauri have been derived from North Korea's liquid-fuel Nodong, which has a range of approximately 1,300 kilometres, giving it the ability to strike Israel when launched from the western borders of Iran. Israel has built and deployed Jericho-2 while Pakistan has fielded Shaheen-2 and India with Agni-2 and Agni-3 whereas North Korea's Taepodong-2 has been tested unsuccessfully. Jericho-2, Shaheen-2, Taepodong-2, Agni-2 and Agni-3 are all two-stage missiles.

The five Non-Proliferation Treaty (NPT)-defined states have ICBMs having range of 5,000-13,000 KM and capability of being launched from submarines (SLBMS).

- The United States possesses 9,000-KM range Minuteman-3 ICBMs and 7,000-KM range Trident-I and Trident-II.³
- Russia currently has ICBMs with ranges of

around 9,000 KM. They are mainly derived from the liquid-fuel SS-18, SS-19, SS-24 and SS-25 technologies.

- France currently possesses the 6,000-KM range M-45 SLBM.
- China has the DF-5, which has a range of 13,000 KM, and has tested new 8,000 KM range DF-31.

International Controls on Missile Proliferation

There are two main global instruments, which aim to contain missile proliferation – the Missile Technology Control Regime (MTCR) and The Hague Code of Conduct. However, the two instruments have been found ineffective in curbing missile proliferation.

The MTCR was initiated partly in response to the increasing proliferation of weapons of mass destruction (WMD), i.e., nuclear, chemical and biological weapons. It was formed in 1987 and seeks to contain missile proliferation by denying the regional powers the technology to build missiles. However, it is fair to assume at this stage that many states already possess the necessary technical skills and expertise to build Intermediate Range Ballistic Missiles (IRBM). Although the MTCR cannot completely prevent missile proliferation, it could still delay states from developing IRBMs and long-range missiles. However, it must be acknowledged that a state determined to develop such programmes could do so despite the regime.

While the MTCR has experienced a reasonable amount of success in slowing and also ending a few missile programmes such as Argentina, Brazil, Egypt, Iraq, Libya, South Africa, South Korea, Syria and Taiwan,⁴ it has also faced a few shortcomings. Countries and cities in the Middle East, South Asia and Northeast Asia have borders, which are separated by less than 300 kilometres. Thus, MTCR is incapable of

²Global Ballistic Missile Arsenal, 2007, Centre for American Progress, http://www.americanprogress.org/issues/2007/05/ballistic_missile_tables.html

³United States Retires MX Missile, Wade Bose, *Arms Control Today*, October 2005.

⁴The Joint Argentine-Iraq-Egypt Condor Missile Programme.

providing security in this kind of scenarios. The MTCR also does not address the already existing ballistic missile arsenals in Third World countries. The MTCR regime also seems to have achieved the goal of preventing the developing countries from gaining access to space through indigenous space launch programmes. This is because space launch programmes have a latent capability to be converted into ballistic missile programs and thus face the prospect of being thwarted by the MTCR guidelines.

According to Jerome et. al⁵ “probably the greatest weakness of the MTCR is the flawed premise upon which the regime is based: technology denial as a long-term solution to proliferation concerns. Supplier cartels do nothing to address the demand for missiles, which is born of regional political tension and local arms races. The developing world views the MTCR with suspicion and hostility; through it they see an attempt by the developed countries to bar their entry into peaceful space activities. Like the NPT, the MTCR is seen as another discriminatory regime in which the North is allowed possession of a certain category of weaponry, and the South is not.”

The Hague Code of Conduct, initiated in 2002, calls upon states to make their missile policies transparent and provide advance notices of their missile and space launches.

Although this can be seen as a confidence-building measure, The Hague Code of Conduct does not prevent missile proliferation activity nor does it offer an incentive to refrain from missile activities.

One of the concepts that help in curbing ballistic missile proliferation is a “flight-test ban”. A missile flight ban would now prove a useful tool to slow (or halt) further missile proliferation. A testing prohibition would be effective because:

a) flight testing is essential to achieve any degree of confidence that a ballistic missile system under development will work as intended; and b) such a ban would be more readily verified than any other arms control agreement imaginable.⁶

Flight Test Bans

The concept of a flight-test ban was first explored in 1950s. It was favoured by the UK and France. There was a partial support from the US since it provided them with the incentive of curbing the development of a Soviet ICBM.

Although this concept proved impossible during the Cold War, a flight-test ban would be of more significance today. Two types of flight-test bans as suggested by Dinshaw Mistry⁷ are:

- Test notifications and moratoriums; and
- Test bans.

The two measures can help in improving the effectiveness of regional missile-free zones and intermediate-range bans. An important ingredient of the code of conduct are test notifications, guidelines (e.g., agreements not to aim test missiles at neighbouring states), and moratoriums. These measures have important political and security benefits since they help in reducing and averting regional crisis. Unannounced flight tests could end up shocking neighbouring countries as was observed with North Korea’s 1998 Taepodong test, thus increasing their security concern, consequently demanding for missiles.

Comprehensive flight-test bans would make the development of new missiles technologically harder and thus prove to be a significant factor in thwarting proliferation. It would help in freeing all states to their present missile capabilities and hinder them from developing new missiles.

⁵ ‘Proposal for a Zero Ballistic Missile Regime’, Jerome Holton, Lora Lumpe and Jeremy Stone, Science and International Security Anthology AAAS: Washington, 1993, pp. 379-396.

⁶ ‘A Flight Test Ban as a Tool for Curbing Ballistic Missile Proliferation’, Lora Lumpe, *INESAP-Information Bulletin No. 4*, January 1995.

⁷ ‘Beyond the MTCR: Building a Comprehensive Regime to Contain Missile Proliferation’, *International Security*, 27.4 (2003), pp.119-149.

Although regional powers may henceforth not have the need for testing SCUD technology, they would still need flight testing to prove essential technologies such as stage separation for long-range missiles, guidance systems and target systems. Flight testing is a very essential and integral part of the missile development process. The procurement route, range, sophistication, mission and the payload of ballistic missiles dictate different flight testing requirements. Missiles tested by the US Navy and Air Force undergo elaborate and strenuous testing sequences.

Early US rockets were tested around 30 to 50 times before they were deployed. Countries like India, France and Israel tested rockets somewhere between five and 12 times before they were deployed.⁸ However, today some countries may be satisfied with very little testing for a variety of reasons, primary one being cost. For example, North Korea's Nodong missile was deployed after a single test. Saudi Arabia purchased an estimated 50 CSS-2s from China in 1998 and there were no reported tests of this missile from Saudi Arabia.

- However, it should be kept in mind that flight testing is essential for developing more powerful and multiple-stage missiles. And in fact, the countries pursuing long-range missile or launch capabilities have serious, methodical flight testing programmes, albeit with fewer flights at less cost than that of the superpowers' programmes. Zero flight testing of a missile results in zero confidence levels. Achieving an acceptable degree of confidence in the reliability of a system, and characterising its accuracy and performance under varying conditions requires operational flight testing. The measure of accuracy, 'circular error of probability', cannot be determined by a

single missile test; rather it can only be estimated by a substantial number of missile tests.

Verification

The objective of monitoring a missile's test flight is to:⁹

- Detect when a flight has occurred;
- Confirm that the trajectory of the flight is not threatening;
- Confirm the type of the missile being tested;
- Determine the range of the test.

A crucial aspect of missile control is verification, at least the effective matching of verification tasks to the available technical means. Verification plays an important role in increasing the confidence in the implementation of a treaty. An effective verification system reliably detects non-compliance and allows abiding states to credibly demonstrate their compliance. It also assists in deterring non-compliance. Verification is imperative for an effective treaty, as in that it provides an objective trigger for enforcement measures and legitimises those measures when they are implemented.¹⁰ Perfect verification, or a complete assurance that the other side has lived up to its promises on the provisions of an agreement, is not necessary to achieve in the implementation of a successful arms control regime.¹¹ In fact, it is not feasible. The essence of a highly effective arms control verification is a reasonably high level of confidence that the other concerned party is living up to its commitments, a high level of deterrent that aids in noncompliant behaviour and also a timely indication that would help in assessing if the party fulfills its commitments.

National or international technical means of

⁸'Two Treaties to Contain Missile Proliferation', Thomas Graham and Dinshaw Mistry, *Disarmament Diplomacy*, Issue No. 82, Spring 2006.

⁹'Verifying Missile Proliferation in Northeast Asia', Michael Vannoni, Kent Biringer, Lawrence Trost, *SANDIA REPORT*, SAND2003-1148, Printed April 2003.

¹⁰'Missile Control Agreements: A General Approach to Monitoring and Verification', Michael Vannoni and Kent Biringer, *Disarmament Forum One*, 2007, pp. 31-42.

¹¹'The INF Treaty and Prospects for Strategic Arms Verification', Robert Summers, *IEEE Technology and Society Magazine*, December 1990.

verification for missile control could focus on the observable rocket characteristics such as number, size, range, payload, deployment mode, launch preparations and flight trajectory. Infrastructure for missile programmes and their corresponding production facilities, test ranges, static test facilities, tracking and communication facilities, missile containers and missile carrying vehicles are also highly observable.¹²

Verification is a challenging activity since a determined violator can secretly build missiles in underground factories and bunkers. Three points suggest that verification is still considered feasible:

1) Firstly, it would be fair to assume at this stage that states possess enough technical expertise to monitor missile agreements. The verification of the START and INF treaties, the work of the UN Special Commission (UNSCOM) and the UN Monitoring, Verification and Inspection Commission (UNMOVIC) in Iraq has demonstrated several techniques of verification. These experiences have also shown that unperturbed swift access to the suspect sites is required in order to detect the evidence of noncompliance.

2) There are always drawbacks associated with any verification regime. Although a verification regime might not detect every single missile component, it should be noted that these components have to be integrated and new missiles have to be tested leading the possibility of flight tests being detected.

3) Verification of flight tests is relatively easy. Missiles in their early stage of development are often launched from fixed complexes, which include launch pads and other necessary infrastructure. Activities from these infrastructures can be observed through satellites.

Missile launches can be observed through satellites, ground-based radars and infrasound sensors as described below:

Verification Technologies

Remote Sensing

Satellite imagery and images from aircrafts would be very useful in detecting preparations for a test flight, static testing, and missiles on launch pads. They would also aid in the observation of post-launch effects such as burn marks. For the positive identification of the type of a missile, one would require an image, which would have a resolution lesser than or equal to 50cm. The ultimate effectiveness of commercial imagery satellites are prohibitive because of their spatial resolution and revisit times.

Moreover, the observables associated with a test launch are transient and relatively small in physical size, which further limit the effectiveness of commercial satellite images. Images from aircraft could overcome these difficulties. Images from aircraft have better resolution and the scheduling of revisit times is flexible. Random, short-notice overflights could reduce the number of flights required since a country considering evasive testing would be unfamiliar with the flight schedules. Optical sensors on both commercial satellites and aircraft are limited by weather conditions and darkness. This problem can be overcome by Synthetic Aperture Radars (SAR).

Radars

Ground-based radars can detect test missiles 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 a country or in extreme geographical terrains such as mountains. However, these limitations can be overcome with the help of sophisticated military radars, which overcome the line-of-sight problems using very large antennas. These antennas are capable of sending and receiving signals over the horizon at ranges of several thousand kilometres. One possible cooperative approach

¹² 'Moving Beyond Missile Defense: The Search for Alternatives to the Missile Race', Juergen Scheffran, International Network of Engineers and Scientists Against Proliferation, *Bulletin No. 18*, September 2001.

would be to position small, autonomously operated radar at the test site. This system shall assist in the detection and estimation of the initial trajectory for launches. The second option would be to include a beacon on the test missile, which would announce the missile's launch and assist tracking by radars located outside the country. This beacon would be the same as those used in¹² the commercial aircraft that would enable tracking by civilian flight control radars, which provide nearly complete, worldwide coverage. Radars have also been used for detecting ballistic missile launches for missile defence applications.

The radar systems for detecting and tracking ballistic missile are much larger than those of aircraft detection systems. Such radars have a range of approximately 3,700 to 5,600 kilometres.¹³ The average power of the transmitter for a Ballistic Missile Defence (BMD) radar can be from several hundred kilowatts to one megawatt. And the frequencies of the radar systems for long-range ballistic missile detection are commonly found at the lower realms (the bands are typically at 420-450 MHz and 1,215-1400 MHz).

Infrared Monitoring Satellites for Boost Phase Detection

Monitoring rocket plumes in launch and boost phases provides the greatest global coverage into areas difficult to reach with standard ground radars. The method of detecting missile plumes from space explained in detail by Forden¹⁴ is explained in this paper. The combustion chamber accounts for the combustion of fuels in a missile.

The resulting plume consists of an optical light, which consists of electronic transitions in highly excited atomic species and the infrared emissions with the vibrational status of the combustion products. The phenomenology for

the associated plumes is slightly different for a solid propellant missile from a liquid one. This is primarily due to the presence of aluminum particles associated with it, which results in a significant amount of black-body radiation. Nonetheless, solid propellant motors also produce significant radiation like liquid propellant ones.

Reflection of sunlight off clouds or the earth itself accounts for most of the backgrounds to detect missile plumes. Fortunately, the bands that are of interest in the detection of infrared missile plumes correspond to the light originating from vibration of water molecules and have a wavelength of approximately 2.7 microns, which corresponds to the minimum of the two backgrounds. In addition, there is once again a natural reduction in most backgrounds when the missile plumes are seen in water bands.

The absorption reduces the plume's signal and also the corresponding solar background as a function of height. This is because sunlight has to pass twice through the atmosphere, once it is reflected from the cloud surface and once after. Thus, for a missile and cloud at the same altitude, for instance at 10 kilometres, the cloud brightness relative to the missile plume appears to be five per cent of what it would be without atmospheric absorption. And clouds at an altitude of 10 kilometres are much less common than lower level clouds, a fact that further reduces the average background. Such high-altitude clouds have been responsible for causing false alarms, one of which was in 1985.

Infrasound Monitoring

A wide variety of sources, both human and natural origin, generate infrasound, which is an inaudible sound with frequencies below the human hearing threshold of 20 Hz. The lower frequency cut-off infrasound is limited by the thickness of the atmosphere or a ducting atmospheric layer. In general, infrasound is

¹³'Countermeasures: A Technical Evaluation of the Operational Effectiveness of the Planned US National Missile Defense System', Andrew Sessler et al, Project by Union of Concerned Scientists, USA and Massachusetts Institute of Technology, 2000.

¹⁴'A Constellation of Satellites for Shared Missile Launch Surveillance', Geoffrey E. Forden, *White Paper*, Massachusetts Institute of Technology, 2006.

measured within a frequency range of 0.005 (200s) to 20 Hz. Within this frequency band, a lot of sources of both known and unknown origin generate infrasound. Impulsive sources are, for example, sonic booms, explosions, nuclear tests and meteors. Sources that can often be detected for hours or days are volcanoes, sea waves, mountain associated waves and aurora.¹⁵

Undeclared launches could be detected by use of infrasound and hydro-acoustic sensors similar to those currently employed by the International Monitoring System (IMS) of the Preparatory Commission of the Comprehensive Test Ban Treaty Organisation (CTBTO).¹⁶ These sensors detect sound waves traveling through the oceans and atmosphere, and would be a cost-effective way to verify sea and airborne launches in areas that may be difficult to reach with radars.¹⁷

Figure 2 shows infrasound signals of a Long March rocket being observed at I34MN station of the IMS on October 15, 2003.¹⁸

It should be pointed out that infrasonic wave propagation is in first order dependent on the wind and temperature structure of the atmosphere. Both down wind and a high temperature are favourable conditions for wave propagation. Furthermore, a temperature inversion, increasing temperature with height can cause infrasonic wave to bend back towards the earth's atmosphere.

On Site Inspection

Inspectors, as a part of on-site inspections, were first used systematically to assess conditions at military related facilities under the 1919 Treaty of Versailles.¹⁹ On-site inspections involve considerable degree of intrusiveness, which give rise to a question of political acceptance. The level of intrusiveness for a pre-launch

inspection involves a cursory inspection of the launcher exteriors.

The other factors, which would aid verification, are the information about the fuel, payload, flight trajectory and other relevant flight data. In order to determine the particular payload type – particularly to detect re-entry vehicles at the front of a rocket – without disclosing proprietary information, nonintrusive techniques can be applied such as scanning and radiographic devices. Mutually complementary equipment for different regions of the radiation spectrum can be applied.

For example, nuclear radiation detection could be employed for searching alpha, beta and gamma decay, thus indicating the presence of nuclear materials. Similarly, neutron detection would aid in the indication of information about the types of materials used, particularly in the detection of explosives. Basic design information with the preservation of commercial interests could be obtained through X-ray equipment.

Precision X-ray, computer tomography and in exceptional circumstances opening of the payload in the presence of inspectors shall help alleviate the concerns regarding uncertainties about non-compliance. However, the measures would require a significant amount of openness by the host state. Verification problems are easier to solve when there is willingness on part of the states to cooperate and exchange information.

Confidential data management policies such as ones practiced by the Organisation for Prevention of Chemical Weapons (OPCW) and the International Atomic Energy Agency (IAEA) can help mitigate concerns about the protection of sensitive commercial or security-related information.

¹⁵'Infrasound Monitoring in the Netherlands', Laslo Evers, *Journal Netherlands Acoustics Group*, No. 176, September 2005.

¹⁶'Verification Technologies: Infrasound, Comprehensive Test Ban Treaty Organization', www.ctbto.org

¹⁷'Infrasound as a Tool for CTBT Verification', Hein Haak and Laslo Evers, *Verification Yearbook 2002*, pp. 207-221.

¹⁸'Latest Developments in the Automatic and Interactive Processing of Infrasound Data at the IDC', Nicolas Brachet, John Coyne and Ronan Le Bras, *Infrasound Technology Workshop*, Fairbanks, Alaska, September 2006.

¹⁹'Missile Control Agreements: A General Approach to Monitoring and Verification', Michael Vannoni and Kent Biringner, *Disarmament Forum*, 2002.

Table 1²⁰ lists out approximately the costs and drawback involved in these verification mechanisms. The table also demonstrates the scope of the verification mechanisms and their advantages and disadvantages, respectively.

Verification Mechanism	Approximate Cost of set up (million US\$)	Operational Cost (million US\$ per year)	Confidence Gaps
Declaration and pre-launch payload inspections would increase and decrease costs of verification, but inspections would only verify deployment/non-deployment use			
Detection of undeclared launches On-site inspections Infrasound and hydro-acoustics Ground-based detection radars Infra-red monitoring satellites	10-50 Costs vary from 10-100 Greater than 500	10-50 Costs vary from 10-50 Costs vary from 10-100	Launches in air Trajectory detection Assuring global coverage
Verification of in laboratory testings Laboratory inspections	10-50	10-50	Laboratories are easily concealed; dual-use problems are enormous

Ballistic Missile Programme as Satellite Launch Vehicle Programmes

As mentioned elsewhere in this paper, countries often mask their ballistic missile programmes as satellite launch vehicle (SLV) programmes, which make verification difficult. While there exists a substantial gap between a civilian nuclear power plant and a power plant intended for military purposes, the gap between an SLV and a ballistic missile is extremely short in terms of technology. The following instances

have highlighted this concern.

The Iranian space agency was set up in 1998 and its space programme is aimed at developing SLV capabilities as well as a satellite. The SLV development is closely twinned with the ballistic missile development. In January 2007, Iranian officials stated that the Iranian space launcher, based on the larger version of Shahab-3 missile design, had been assembled and “will lift off soon” with an Iranian satellite. And in February 2007, Iran tested its first sub-orbital rocket. The rocket reached an altitude of 150 kilometres before falling back to the earth and deploying a parachute for recovery. Iran claimed that the rocket was intended for research and part of its goal of launching Iranian manufactured satellites on Iranian manufactured rockets. It is estimated that the rocket’s operational range against a ground target might be approximately 300 kilometres.

It is assumed that the rocket was tested using a Shahab-3 or a Ghadr engine. Iranian officials often discuss space and missile developments simultaneously, perhaps indicating the parallel nature of the programmes. They have openly admitted that the Shahab missile system has been used as the basis for developing Iran’s SLV.²¹ In fact, Nasser Maleki, deputy director of Aerospace Industries Organisation (AIO), openly acknowledged that the same technology used for building an SLV could be used to manufacture missiles.²²

The North Korean ballistic missile programme is another example of an integrated rocket science programme with both military and civilian applications. Furthermore, on August 31, 1998 North Korea used the Taepodong-I missile in a failed attempt to launch the Kwangmyngsyng-1 satellite into a Low Earth Orbit. North Korea has also been trying to obtain assistance from Russia for its SLV

²⁰ ‘Verification Models for Space Weapons Treaties: A Flexible, Layered Approach as a Negotiating Tool’, Richard A. Bruneau and Scott G. Lofquist-Morgan, *Building the Architecture for Sustainable Space Security, Conference Report*, 30-31 March, 2006, pp. 67-92.

²¹ On July 22, 1998, Iran launched its first test flight of the Shahab-3 missile, which coincided with its announcement of a space programme. See ‘Iran Missile Chronology,’ *Nuclear Threat Initiative*, May 2002, http://www.nti.org/e_research/profiles/Iran/Missile/1788_1813.html.

²² ‘Aerospace Official Says Iran’s Missile Technology Peaceful, Fulfills, Space Needs’, *Voice of the Islamic Republic of Iran, Radio*, FBIS IAP20041020000094, Oct 20, 2004.

programme, which it claims is entirely for civilian purposes. North Korea is in the process of developing its Taepodong-2 missile, which is estimated to have a range of 10,000 kilometres and is nuclear capable.

The 20th anniversary of the Missile Technology Control Regime (MTCR) held in Copenhagen in May 2007 acknowledged the prevalence of a serious concern that some nations may camouflage their ballistic missile programme as SLV programme, and that ICBM test flights may be conducted in a space launch configuration.²³

Conclusion

Verification is not just a technical but also an important political problem. One of the major pledges in the nuclear non-proliferation treaty is the commitment to nuclear arms reduction. The military flight-test ban might help aiding this commitment. By banning military flight tests, the chances of an accidental or intentional nuclear war through continued development of strategic missiles can also be significantly decreased. A flight-test ban would also aid in reducing the need for missile defence systems, lessening global tensions and freeing up resources that would be spent to develop and deploy such systems.

Flight testing restrictions shall certainly hamper and even make impossible the spread of long-range missile capability. A clear understanding of the technologies, verification possibilities and costs will facilitate the negotiation and implementation of the flight-test ban treaty. The technical, political and financial feasibility of the verification measures will shape the treaty negotiation and implementation. Effective multilateral verification can legitimise and facilitate enforcement mechanisms and increase the effectiveness of the treaty as a whole.

Appendix A

Measures to Distinguish Between Ballistic Missile Flight Tests and Space Flights

Some of the technical characteristics, which would enable differentiation between the ballistic missile tests and space flights, are listed below:

Boost Phase

States party to the flight-test ban should list out the relevant technical specifications such as length, diameter of the flight motors to be tested. In the case of boosters identical to space launch vehicles, the boosters must be displayed for inspection, counting and tagging.

Reentry

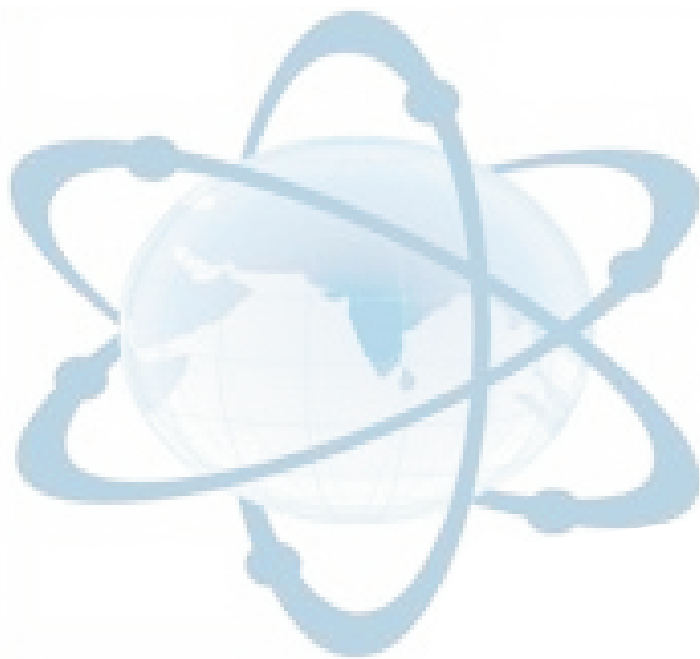
Ballistic missile reentry vehicles approach or impact the earth at many times the speed of sound; accuracy would diminish if they were slower and spent more time in the atmosphere. High-speed reentry is not used in space programmes. And infrasound detectors are capable of picking signals from space vehicles reentering the atmosphere. Classification of infrasound signals can help in identifying the reentry event thus enabling verifying flight-test bans.

Warhead Separation Phase

The weights and profiles of existing reentry vehicles could be catalogued, and the release of objects sharing the weight and velocity change of missile reentry vehicles could be then banned.

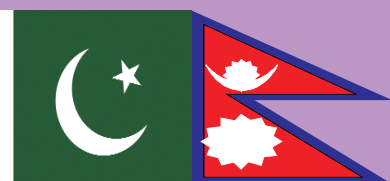
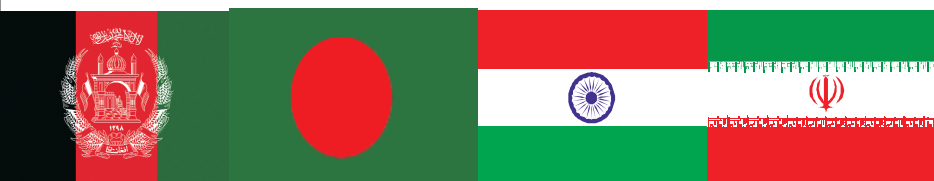
[The author is a postdoctoral associate at Cornell University. He can be reached at bg265@cornell.edu]

²³OpEd: SLV Assistance or Missile Proliferation?, Victor Zaboriskiy, *SpaceNews.com*, May 29, 2007.



SASSI is a specialist research institute based in London, UK with a branch office in Islamabad, Pakistan. The institute is at the forefront of Weapons of Mass Destruction, Arms Control and Disarmament research on South Asia.

Its partners have included the UN, NATO, the EU, prestigious academic institutions, scholars and many governments.



SASSI Research Report No. 15, Ghani Jafar, *West Asian Implications of the Iranian Nuclear Programme*

SASSI Research Report No. 16, Jack Boureston, *Understanding Pakistan's Energy Security Needs and the Role of Nuclear Energy*

SASSI Research Report No. 12, Gaurav Rajen, *Nuclear Export Controls in India; A review of Existing Systems and Prospects for Enhanced India-US Cooperation*

SASSI Research Report No. 11, Maria Sultan and Dr. Zulfiqar Khan, *The Implication of Pre-emptive Strategy on the Safety and security of Pakistan's Nuclear Arsenal: Post September 11*

SASSI Research Report No. 10, Gurmeet Kanwal, *Indo-US Nuclear Deal: Implications for Non-Proliferation*

SASSI Research Report No. 9, Zafar Nawaz Jaspal, *The Indo-US Strategic Relationship and Pakistan's Security*

SASSI Research Report No. 8, Bharath Gopalaswamy, *Preventing Ballistic Missile Proliferation through Flight Test Bans: A Look at Verification Technologies*

SASSI Research Report No. 7, Nasrullah Mirza and M. Sadiq, *Indo-US 123 Agreement; Impacts on Deterrence Stability in South Asia*

SASSI Research Report No. 18, Ian Bremmer & Maria Kuusisto, *Pakistan's Nuclear Command and Control; Perception Matters*

SASSI Research Report No. 17, Deba R. Mohanty, *The Arms Dynamic and Strategic Stability in South Asia: Current Trends*

SASSI Research Report No. 5, Gaurav Rajen, *The Problematic of a Nuclear Force in-Being a Stable Deterrence and the Issue of Non-Deployment, February 2006*

SASSI Research Report No. 4, Rifaat Hussain, *Nuclear Doctrines in South Asia, December 2005*

SASSI Research Report No. 3, Shaun Gregory, *Rethinking Strategic Stability in South Asia, September 2005*

SASSI Research Report No. 2, Suba Chandran, *Building Trust and Reducing Risks; Nuclear Confidence Building in South Asia, July 2005*

SASSI Research Report No. 1, Rodney W. Jones, *Conventional Military Imbalance and Strategic Stability In South Asia, March 2005*

SASSI Research Papers

SASSI Research Paper No. 19, Upendra Choudhury, *The Indo-US Nuclear Deal and Its Impact on India's Ballistic Missile Programme*

SASSI Research Paper No. 14, Naeem Haider, *The Significance of National Implementation Measures Under the Chemical Weapons Convention; Guarding Against Terrorist Use of Commercial and Industrial Chemicals*

SASSI Research Paper No. 13, Stephen Blank, *India's Energy Option in Central Asia*

SASSI Research Paper No. 4, *What Stability-Instability Paradox? Sub-national Conflicts and the Nuclear Risk in South Asia*, by Rajesh Rajagopalan, February 2006

SASSI Research Paper No. 3, Ambassador Thomas Graham, *The U.S.-India Joint Declaration; Trade, Non-proliferation and Security, November 2005*

SASSI Research Paper No. 2, Shabana Fayyaz, *A Break from the Past; Trends in Pakistan's Security Policy After 9/11, August 2005*

SASSI Research Paper No. 1, Zafar Nawaz Jaspal, *Arm Control; Risk reduction Measures Between India and Pakistan, June 2005*



SASSI

London Headquarters
36 Alie Street, Aldgate, London, E1 8DA
Tel: + 44 (0) 845 003 0864
Fax: + 44 (0) 127 434 7295

SASSI

Pakistan Bureau
Street # 1, House # 427, F-11/1, Islamabad - Pakistan
Tel: +92 (51) 229 0917, 229 1061
Fax: +92 (51) 210 3479

All copy rights belong to SASSI