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

By Bharath Gopalaswamy • Series Editor: Maria Sultan

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-Bharath Gopalaswamy

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 on developing long range systems. Verification technologies such as remote sensing, infrasound monitoring have been discussed. One particular concern on the missile nonproliferation agenda is that of satellite launch vehicles (SLVs) has also been addressed.

Introduction

Missiles are an important component in the world's military arsenals and are the key delivery system for nuclear, biological and chemical weapons. Missiles have an important role for war in a well organized military structure. In addition, missiles are used as nationalist symbols. Currently, many states in the world possess short-range missiles whose mission is to lend support for military activities on the battlefield. It should be pointed out that the political and psychological reactions to missiles are greater than their actual effect on the ground. This could be attributed to the public's feeling of helplessness. 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 although 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, their ability to carry conventional and nuclear payloads and a great difficulty in defending against them. Missile non-proliferation arrangements have a lot in common with nuclear nonproliferation efforts. The major underlying concern regarding missile proliferation is the threat of deliberate or unauthorized diversion of dual-use technologies, equipment and expertise from the originally intended civilian applications to military purposes.

Verification and safeguards mechanism is an issue missile nonproliferation 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 programs absolutely missile proliferation-safe, it is at least worth to look at technologies, which can assist in monitoring these proliferation 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 program; dual-use is the main problem that must be overcome. With space co-operation 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. With the assistance of remote sensing 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 depend 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 (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

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 range missiles.

Around seventeen countries in the world today have only short range ballistic missiles deployed. Around six countries have short and medium range ballistic missile 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 IRBM's. Iran's Shahab-3 and Pakistan's Ghauri have been derived from North Korea's liquid fueled Nodong, which has a range of approximately 1,300 kilometers' 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, Taepodon-2, Agni-2 and Agni-3 are all two stage missiles.

The five non-proliferation treaty (NPT)-defined states have 5,000-13,000 kilometers range ICBM's and missile capable of being launched from submarines (SLBMS).

- The United States possesses 9,000 Km range Minuteman-3 ICBM's and 7,000 Km range Trident-I and Trident-II[3]
- Russia currently has ICBM's of ranges of around 9,000 Km. They are mainly derived from the liquid fueled 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, these two instruments have been found to be 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 it seeks to contain missile proliferation by denying the regional

[1] Centre for Defence and International Studies (UK) (www.cdiss.org/bmrange.htm)
[2] Global Ballistic Missile Arsenal, 2007, Centre for American Progress, http://www.americanprogress.org/issues/2007/05/ballistic_missile_tables.html

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

powers the technology to build missiles. However, it is fair to assume at this stage many states already possess the necessary technical skills and expertise to build Inter-Mediate Range Ballistic Missiles (IRBM). Although the MTCR cannot completely prevent missile proliferation it could still delay states from developing IRBM's and long range missiles although it must be acknowledged that a state determined to develop such programs could do so despite the regime.

While the MTCR has experienced a reasonable amount of success in slowing and also ending a few missile programs 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 North-East Asia have borders, which are separated by less than 300 kilometers. Thus, MTCR is incapable of providing security in these kinds 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 developing countries from gaining access to space through indigenous space launch programs. This is because space launch programs 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. al[5] "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 to 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 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 1950's. It was favored by the UK and France. There was a partial support

[4] The Joint Argentine-Iraq-Egypt Condor Missile Program

[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.

from the USA 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 Mistry[7] are:

- Test notifications and moratoriums and
- Test bans

These 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 neighboring 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 neighboring 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 freezing all states to their present missile capabilities and hinder them from developing new missiles. 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 targeting 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 5 to 12 times before they were deployed.[8] However, some countries today may be satisfied with very little testing for a variety of reasons, primary one being cost. For example, North Korea's No-dong 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, countries, which pursue long-range missile or launch capabilities have serious, methodical flight testing programs, albeit with fewer flights at less cost than that of the superpowers' programs. Zero flight testing of a missile results in zero confidence levels. Achieving an acceptable degree of confidence in the reliability of a system, and characterizing its accuracy and performance under varying conditions, requires operational flight testing. The measure of accuracy 'circular error of probability (CEP), cannot be determined by a single missile test; rather it can only be estimated by a substantial number of missile tests.

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

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

Verification

The objective of monitoring a test missile's 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, not 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 in that it provides an objective trigger for enforcement measures and legitimizes 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 behavior and also a timely indication that would help in assessing if the party fulfills its commitments. National or international technical means of 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 programs 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 non-compliance.
2) There are always drawbacks associated with any verification

[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, Dec 1990.

[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.

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 from satellites.

Missile launches can be observed from 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. In order for the positive identification of the type of 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 over flights 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 aircrafts 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 the 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 kilometers. One possible co-operative approach would be to position small, autonomously operated radar at the test site. This system shall assist in the detection and the 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 in

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 Defense 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 kilometers.[13] The average power of the transmitter for a ballistic missile defense (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 is explained in detail by Forden[14] 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 than a liquid one. This is primarily due to the presence of aluminum particles associated with it, which results in a significant amount of

blackbody radiation. Nonetheless, solid propellant motors also produce significant radiation like liquid propellant ones.

Reflect sunlight off clouds or the earth itself account for most of the backgrounds to detecting 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 these 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 kilometers', the cloud brightness relative to the missile plume appears to be 5% of what it would be without atmospheric absorption. And clouds at 10 kilometers altitude are much

[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.

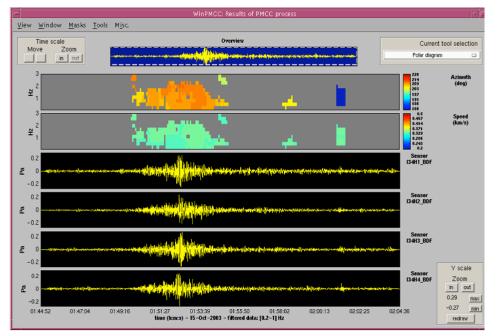
less common than lower level clouds, a fact that further reduces the average background. Such, high altitude clouds have been in responsible in causing false alarms, one of which was in 1985.

- **Infrasound Monitoring**

A wide variety of sources both human and natural origin generate infrasound. Infrasound is 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 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 Organization (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 15th October 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 favorable conditions for wave propagation. Furthermore, a temperature inversion, increasing temperature with height can cause infrasonic to bend back towards the earth's atmosphere.

- **On Site Inspection**

[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.

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-in particular, to detect re-entry vehicles at the front of a rocket- without disclosing proprietary information, non-intrusive 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 equipments. 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 regarding non-compliance. However, these measures would require a significant amount of openness by the host state. Verification problems are made easier to solve when there is willingness on part of the states to co-operate and to exchange information. Confidential data management policies such as ones practiced by the Organization 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.

Table 1[20] 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.

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[19] Missile Control Agreements: a general approach to monitoring and verification, Michael Vannoni and Kent Biringer, Disarmament Forum, 2002.

[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.

Verification mechanism	Approximate costs of set up (US$ in millions)	Operational costs (per year) (US$ in millions)	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 un-declared 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 Program as Satellite Launch Vehicle (SLV) Programs

As mentioned elsewhere in this paper, countries often mask their ballistic missile programs as SLV programs, 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 a space launch vehicle (SLV) and a ballistic missile is extremely short in terms of technology. The following instances have highlighted this concern.

The Iranian space agency was formed in 1998 and its space program is aimed at developing SLV capabilities as well as a satellite. The SLV developments are closely twinned with their 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 kilometers 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 kilometers

Assuming 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 programs. They have openly admitted that the Shahab missile system has been used as the basis for developing Iran's space launch vehicle (SLV).[21] In fact, Nasser Maleki, deputy director of Aerospace Industries Organization (AIO), openly acknowledged that the same technology used for building a space launch vehicle could be used to manufacture missiles.[22]

The North Korean ballistic missile program is another example, which demonstrates the

[21] On July 22, 1998, Iran launched its first test flight of the Shahab-3 missile, which coincided with its announcement of a space program. 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, Fulfils, 'Space Needs'," Voice of the Islamic Republic of Iran, Radio, FBIS IAP20041020000094, Oct 20, 2004.

example of an integrated rocket science program 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 program, which it claims is entirely for civilian purposes. North Korea is in the process of developing its Taepodong-2 missile. Taepodong-2 missile is estimated to have a range of 10,000 kilometers' and is nuclear capable.

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

Conclusions

Verification is not just a technical problem but also an important political one too. 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 defense 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 and 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 treaty negotiations and implementations. Effective multilateral verification can legitimize and facilitate enforcement mechanisms and increase the effectiveness of the treaty as a whole.

[23] OpEd: SLV Assistance or Missile Proliferation?, Victor Zaborskiy, SpaceNews.com, May 29, 2007.

Appendix A

Measures to Distinguish Between Ballistic Missile Flight Tests and Space Flights

Some of the technical characteristics, which would enable differentiating between 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 a 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 programs. And infrasound detectors are capable of picking signals from space vehicles re-entering the atmosphere. Classification of infrasound signals can help in identifying the re-entry 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.

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