an IISS strategic dossier

IRAN'S BALLISTIC MISSILE CAPABILITIES

A net assessment

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This publication has been prepared by the Director-General and Chief Executive of the Institute and his staff. It incorporates commissioned contributions from recognized subject experts, which were reviewed by a range of experts in the field. The IISS would like to thank the various individuals who contributed their expertise to the compilation of this dossier. The responsibility for the contents is ours alone. The views expressed herein do not, and indeed cannot, represent a consensus of views among the worldwide membership of the Institute as a whole.

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cover images: Cover images: Top: Test-firing of a *Sajjil*-2, undisclosed location in Iran, 16 December 2009 (Vahi Reza Alaee/AFP/Getty Images). Bottom, from left to right: New Iranian solid-fuelled *Sajjil*-2 missile, displayed at undisclosed location in Iran prior to its test-firing on 20 May 2009 (AFP/Getty Images); Iranian officials looking at a cluster engine display for a future satellite booster rocket, Tehran, 3 February 2010 (AP); Iranian government officials standing beneath a mock-up of the projected *Simorgh* space-launch vehicle during the unveiling ceremony, Tehran, 3 February 2010 (Rohollah Vahdati/AFP/Getty Images).

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Common Abbreviations

ASLV	Augmented Satellite Launch Vehicle
AWACS	Advanced Warning and Control System
CEP	Circular Error Probable
CRBN	Chemical, Biological, Radiological and Nuclear
DIO	Defense Industries Organization
DPRK	Democratic People's Republic of Korea
DSTC	Defence Science and Technology Commission
EPW	Electronic Pulse Weapon
GPS	Global Positioning System
HEU	Highly Enriched Uranium
IAEA	International Atomic Energy Agency
ICBM	Intercontinental Ballistic Missile
ICOC	International Code of Conduct against Ballistic Missile Proliferation
IGMDP	Integrated Guided Missile Development Programme
IRBM	Intermediate Range Ballistic Missile
IRGC	Iranian Revolutionary Guards Corps
LRBM	Long-Range Ballistic Missile
MKO	Mojahedin-e Khalq Organization
MRBM	Medium-Range Ballistic Missile
MTCR	Missile Technology Control Regime
NATO	North Atlantic Treaty Organisation
NCRI	National Council of Resistance in Iran
PSI	Proliferation Security Initiative
PSLV	Polar Satellite Launch Vehicle
R&D	research and development
RPP	Rocket Propellant Plant
RV	Re-entry Vehicle
SBIG	Shahid Bagheri Industrial Group
SLV	Satellite Launch Vehicle
SPRG	Solid Propellant Research Group
SRBM	Short-Range Ballistic Missile
SUA	Convention for the Suppression of Unlawful Acts Against the Safety of Maritime Navigation
TEL	Transporter-Erector-Launcher
UAV	Unmanned Aerial Vehicle
UNCOPUOS	United Nations' Committee on the Peaceful Uses of Outer Space
WMD	Weapon(s) of Mass Destruction

Iranian Rockets and Missiles

Missile	Translation	Fuel type	Estimated range	Payload
Fajr-3	*Dawn*-3	Solid	45km	45kg
Fajr-5	*Dawn*-5	Solid	75km	90kg
Fateh-110	*Victorious*	Solid	200km	500kg
Ghadr-1	*Powerful*-1	Liquid	1600km	750kg
Iran-130 / *Nazeat*	*Removal*	Solid	90–120km	150kg
Kh-55		Liquid	2500–3000km	400–450kg
Nazeat-6	*Removal*-6	Solid	100 km	150kg
Nazeat-10	*Removal*-10	Solid	140–150km	250kg
Oghab	*Eagle*	Solid	40km	70kg
Sajjil-2	*Baked Clay*-2	Solid	2200–2400km	750kg
Shahab-1	*Meteor*-1	Liquid	300km	1000kg
Shahab -2	*Meteor*-2	Liquid	500km	730kg
Shahab-3	*Meteor*-3	Liquid	800–1000km	760–1100kg
Shahin-1	*Hawk*-1	Solid	13km	
Shahin-2	*Hawk*-2	Solid	20km	
Zelzal-1	*Earthquake*-1	Solid	125km	600 kg
Zelzal-2	*Earthquake*-2	Solid	200km	600 kg


Missile silo construction reported near here
Tabriz
Production facilities for *Oghab*, *Fateh*-110, *Iran*-130/*Nazeat* and *Zelzal* rockets
Missile test facility
IRGC airbase missile launch site near this city
Sahroud
Mashhad
Sajjid base where *Zelzal* missiles are reportedly deployed
Karaj
Tehran
Semnan
SEMNAN
Iranian Space Centre
Khorramabad
Site of missile testing ground
Esfahan
Madiseh
IRAN
Missile silo construction reported near here
Dasht-e Lut desert
Shiraz
Zahedan
Reported site of liquid-propellant production facility
Possible missile production support facilities
Km 200
Miles 200
© IISS

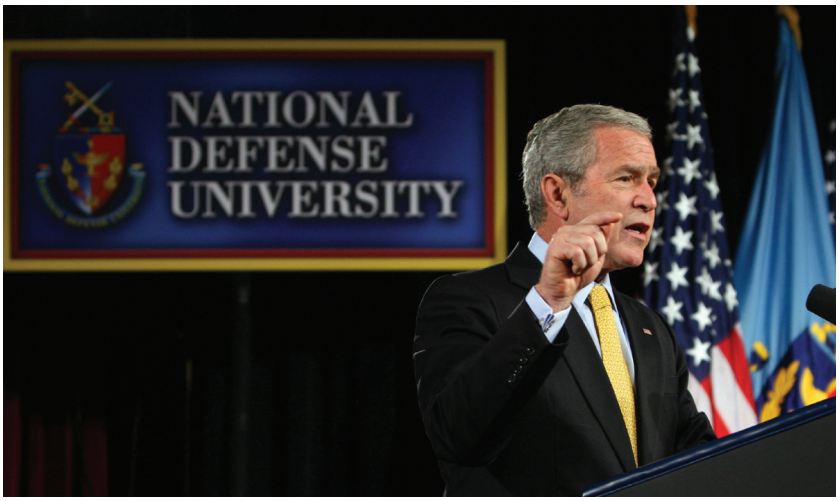
Introduction

In tandem with its efforts to expand its nuclear capabilities, the Islamic Republic of Iran is making robust strides in developing ballistic missiles. The two programmes appear to be connected, with the aim of giving Iran the capability to deliver nuclear warheads beyond its borders, though Iran steadfastly denies any interest in nuclear weapons and claims that its missiles are strictly defensive in nature.[1] In February 2010, the International Atomic Energy Agency (IAEA) said the information it had collected raised concerns about 'activities related to the development of a nuclear payload for a missile'.[2] As of the beginning of 2010, Iran was judged not to possess any nuclear weapons and the country was not expected to possess the ability to threaten neighbours with nuclear-armed missiles for some years. Nevertheless, missiles in its inventory are inherently nuclear capable, if the warheads are sufficiently compact. Iran's longest-range missiles are capable of reaching, inter alia, Israel, Turkey, the Arab Gulf states and parts of southern Russia and southeastern Europe.

Since their advent in the Second World War, ballistic missiles have served mainly to further political and strategic deterrence objectives, rather than to achieve tactical military objectives. Armed with conventional warheads, ballistic missiles deployed in large numbers can be used to sow terror among enemy populations and to pressure adversary governments. The destruction typically caused by ballistic missiles is limited, however, unless they are armed with nuclear weapons. Conversely, the possession of nuclear devices is of little use unless they can be deployed against an external target. While nuclear weapons can be delivered by vessel or land conveyance – either of which might be the vehicle of choice for terrorist groups seeking to obtain nuclear weapons – all nation-states that have acquired nuclear weapons have opted for an air route for reasons of operational security and command and control reliability.[3] For air delivery, missiles are generally preferred over aircraft because of their speed, penetration and long reach.

Concerns about Iran's intentions were fanned in 2004 by evidence, as yet unconfirmed, that at least until 2003 Iran had been working on designs for a missile re-entry vehicle carrying an object that had the attributes of a nuclear weapon. How far such work progressed and whether it continued or resumed beyond 2003 remains a matter of debate among outside observers and intelligence agencies.[4] It is uncontested, however, that Iran has continued unabated work on the two other pillars of a potential nuclear-weapons programme: fissile-material production capabilities (primarily uranium enrichment but also plutonium); and ballistic missiles.

While Iran has registered significant achievements in both these fields, the country's missile programme is the focus of this dossier. In November 2008, Iran test-fired a solid-fuelled *Sajjil* missile that was capable of delivering a 750kg nuclear weapon approximately 2,200km (or even further, depending on payload weight and missile construction). Additional tests of the *Sajjil* in May, September and December 2009 were also reported to be successful. In February 2009, Iran put a satellite into orbit, successfully employing a two-stage rocket. These achievements extend Iran's missile reach beyond the range of the *Shahab*-3/*Ghadr*-1 liquid-fuelled missiles already in Iran's inventory. The tests further show that Iran has established the industrial infrastructure and technological foundations to begin indigenous development of larger, more powerful rocket motors if it chooses to do so. These developments are thus similar to those achieved by Iran in the nuclear arena. As discussed in detail in this



Chris Kleponis/Bloomberg via Getty Images

In a speech at the National Defense University on 23 October 2007, US President George W. Bush announced plans for missile defence deployments in Europe and cited intelligence findings that 'with continued foreign assistance, Iran could develop an intercontinental ballistic missile capable of reaching the United States and all of Europe before 2015, if it chooses to do so'.

dossier, the hurdles Iran would face in seeking to develop longer-range missiles are not insurmountable, but any such efforts would be observable at an early stage.

Over the past decade, the conjunction between Iran's nuclear and missile programmes has spurred decisions by the United States and other nations to develop and deploy missile-defence systems. US President George W. Bush's plan to deploy silo-based missile interceptors in Poland and a powerful tracking radar in the Czech Republic, complementing national missile-defence systems in Alaska and California, was designed to defend against potential Iranian intercontinental ballistic missiles. As recently as October 2007, Bush cited the assessment of US intelligence agencies that 'with continued foreign assistance, Iran could develop an intercontinental ballistic missile capable of reaching the United States and all of Europe before 2015, if it chooses to do so'.[5] This had been the US intelligence assessment since 1998, when the Commission to Assess the Ballistic Missile Threat to the United States (commonly known as the Rumsfeld Commission) concluded: 'We judge that Iran now has the technical capability and resources to demonstrate an ICBM-range ballistic missile … within five years of a decision to proceed.' The commission report also argued that 'with the external help now readily available, a nation with a well-developed, Scud-based ballistic missile infrastructure would be able to achieve first flight of a long range missile, up to and including intercontinental ballistic missile (ICBM) range (greater than 5,500 km), within about five years of deciding to do so'.[6] To date, these worst-case scenarios have not played out.

In 2009, the US intelligence community amended its assessment to focus more on the short- and

Definitions

Although the terms 'missile' and 'rocket' are often used interchangeably, a **rocket** is usually considered to be unguided, while a **missile** has a guidance system that steers it toward its intended target. A **ballistic missile** follows a sub-orbital flight path with altitudes of up to several hundred kilometres, during which it is usually only guided during the relatively brief initial boost phase. During subsequent phases – the ballistic phase (when warhead separation occurs) and the re-entry phase – the missile course is generally governed by the laws of orbital mechanics and ballistics. **Cruise missiles**, by contrast, follow flight paths similar to a low-flying aircraft and are guided throughout the flight.

Ballistic missiles are generally categorised into four range classes:

- **Short-range** ballistic missile (SRBM): range of up to 1,000km;
- **Medium-range** ballistic missile (MRBM): range between 1,000km and 3,500km;
- **Intermediate-range** ballistic missile (IRBM), also termed long-range ballistic missile (LRBM): range between 3,500km and 5,500km; and
- **Intercontinental** ballistic missile (ICBM): range greater than 5,500km.

medium-range missile threat posed by Iran. The new intelligence assessment was a major factor cited in President Barack Obama's September 2009 decision to reconfigure the European missile shield into a more mobile, adaptive system based in southeastern Europe. The details of this intelligence assessment remain classified, but a White House fact sheet issued in support of Obama's alternative missile-defence plan said: 'The intelligence community now assesses that the threat from Iran's short- and medium-range ballistic missiles is developing more rapidly than previously projected, while the threat of potential Iranian intercontinental ballistic missile capabilities has been slower to develop than previously estimated.'[7] This dossier reaches a similar conclusion.

Efforts to restrain Iranian missile capabilities

There is no international treaty banning ballistic-missile development or acquisition,[8] nor have there been any diplomatic efforts to negotiate a voluntary commitment by Iran to this effect. International efforts to constrain the Iranian missile programme have concentrated, rather, on the supply side, by controlling exports. The most successful initiative to date has been the **Missile Technology Control Regime** (MTCR), established in 1987 by Canada, France, Germany, Italy, Japan, the United Kingdom and the United States. Membership in this voluntary association has increased over the years – Russia, for example, joined in 1995, and Ukraine in 1998. The Republic of Korea, the latest to join, raised the total membership to 34 in 2001.

The MTCR seeks specifically to limit the spread of missiles, rockets, cruise missiles and unmanned aircraft capable of delivering a 500kg payload to a distance of more than 300km. A set of guidelines define the purpose of the regime and provide the overall structure and rules which inform the policies of member countries and those adhering unilaterally to the guidelines. An annex, which is designed to assist members in implementing export controls, identifies two categories of exports. Category I items, for which the MTCR guidelines call for a strong presumption to deny, include complete rocket systems, production facilities, and major subsystems for rockets or missiles that exceed defined range–payload thresholds. Category II items, which members are urged to be cautious about exporting, but which do not carry a presumption to deny, include dual-use equipment and components that can be used to produce or operate rockets and missiles. Changes to the MTCR guidelines and annex are made by consensus and regime partners regularly exchange information about relevant national export-licensing issues.

The MTCR is not explicitly aimed at any country, but in practice Iran is among its principle targets. In 2003, MTCR members agreed to add 'catch-all' provisions to the guidelines, in order to restrict export of items that are believed to be destined for missile-proliferation programmes even if they are not specifically identified on the MTCR annex or national control lists. Under the catch-all provisions, an export license is required for any trade with an organisation involved in an MTCR Category I missile programme, such as an Iranian facility involved in the production of *Shahab*-3 missiles.

Among countries that export missile technologies, China, India and North Korea are not MTCR members. Nor is Libya, which agreed with the United States and United Kingdom in 2004 to stop exporting missiles. Since 1991, under a bilateral agreement with the US, China has agreed to abide by the original 1987 MTCR guidelines and annex, though not subsequent revisions. The Chinese government's 2004 application for MTCR membership has not been accepted, however, because of allegations it has not stopped exporting missile technologies to Iran. Under the terms of the US–India nuclear cooperation deal initially struck in 2005, India committed to 'harmonization and adherence' to MTCR guidelines.[9] In talks with North Korea beginning in 1996, Washington sought to persuade Pyongyang to adhere to MTCR guidelines and to terminate its missile-development programme, but no agreement was reached before talks ended in 2000, when President Bill Clinton left office.

Since 1987, the MTCR export-control guidelines have made it much harder for states to newly acquire ballistic-missile capabilities. Would-be proliferant states must either seek missile-related materials and technology from North Korea or through the black market. Various efforts have been made to restrict these avenues. Most successfully, the US has used diplomacy to persuade Egypt, Libya, Pakistan and Yemen to cease importing North Korean missiles

and technology. The US has also led various intelligence, military and diplomatic efforts to break up black market networks and to interdict missile-related transfers, and Washington has continued to sanction North Korean entities for missile-proliferation activities, including exports to Iran.

International cooperation to enhance interdiction efforts was given greater attention and structure in 2003 through the establishment of the **Proliferation Security Initiative** (PSI). Participants in this loose-knit grouping, of which there were 95 as of 2010, agree to explore ways to enhance their ability to interdict trafficking of WMD and their delivery systems and related material. The PSI has helped to establish greater intelligence, diplomatic and operational coordination among its partner states, as well as among departments of government within states. Two former US security officials, Robert Joseph and Brendan Melley, recently claimed that the PSI had facilitated dozens of interdictions of goods destined for nuclear and missile programmes in Asia and the Middle East.[10] Although most of the success stories are classified, a US briefing in 2008 indentified five cases, including one in April 2007 that stopped a shipment to Iran of sodium perchlorate, which can be used in making solid rocket propellant for ballistic missiles. The intended Iranian recipient had been barred from receiving certain missile technologies by UN Security Council Resolution 1737.[11]

As a means of delegitimising missile proliferation and to complement the limited membership of the MTCR, a group of EU members succeeded in 2002 in establishing an **International Code of Conduct against Ballistic Missile Proliferation** (ICOC). Also known as The Hague Code of Conduct against Ballistic Missile Proliferation after the city in which it was launched, the ICOC consists of a set of general principles, modest commitments and limited confidence-building measures. Subscribers undertake a political commitment to be vigilant against assisting in the development of ballistic-missile systems capable of delivering weapons of mass destruction. As of 2010, 130 countries had subscribed to the ICOC. Iran is not among this number and was the only country to vote against UN General Assembly resolutions in 2005 and 2008 that endorsed the code.

In 2004, **UN Security Council Resolution 1540** required all states to establish and enforce export controls on WMD, their means of delivery and related materials. The latter were defined as 'materials, equipment and technology covered by relevant multilateral treaties and arrangements, or included on national control lists, which could be used for the design, development, production or use of nuclear, chemical and biological weapons and their means of delivery'.[12] Thus, items on the MTCR annex are covered by the resolution.

In 2005, an amendment to the Convention for the Suppression of Unlawful Acts against the Safety of Maritime Navigation (SUA) extended the international legal basis for conducting maritime interdictions to transactions related to WMD delivery vehicles.

Several country-specific UN Security Council resolutions have barred missile-technology trade with Iran, particularly Resolution 1737, adopted on 23 December 2006, which directs states to prohibit the transit to Iran from their territory or by their nationals of almost all the items listed by the MTCR annex.

About this dossier

The aim of this dossier is to assess Iran's missile capabilities, in order to contribute to the public debate and to governmental decision-making about the strategic challenges presented by Iran. It sheds light, for example, on why the worst-case scenario projected by the Rumsfeld Commission has not materialised for Iran, notwithstanding its *Scud*-missile production capability and recent success in testing two-stage missiles and space-launch vehicles.

This dossier has direct relevance for Europe-based missile-defence plans and efforts to overcome the distrust with which Russia has viewed these plans. US and NATO officials have voiced the hope that Russia can be brought into a cooperative missile-defence effort to address the Iranian threat. At their 6 July 2009 summit in Moscow, Presidents Obama and Dmitry Medvedev agreed to 'continue the discussion concerning the establishment of cooperation in responding to the challenge of ballistic missile proliferation' and to instruct experts to prepare recommendations. In his first major foreign-policy speech, NATO's new secretary-general, Anders Fogh Rasmussen, said, 'We should explore the potential of linking the U.S., NATO

Alexander Zemlianichenko Jr/Bloomberg via Getty Images

US President Barack Obama and Russian President Dmitry Medvedev shake hands at the Kremlin on 6 July 2009 at a press conference at which they announced the two countries would 'continue the discussion concerning the establishment of cooperation in responding to the challenge of ballistic missile proliferation'.

and Russian missile defense.'[13] A starting point for any such cooperation on missile defence will be to come to a shared understanding of the threat. The authors hope this strategic dossier can help to establish this common ground by complementing the missile-threat assessment that the NATO–Russia Council has agreed to undertake and by offering a more extensive perspective than that of the study of Iran's missile and nuclear potential published by the EastWest Institute in May 2009.[14]

Chapter one of this dossier offers a detailed assessment of each of Iran's liquid-fuelled missiles, with a particular focus on the 1,600km-range *Ghadr*-1, which evolved from the *Shahab*-3, and on the two-stage *Safir* space-launch vehicle. Chapter two provides a detailed assessment of Iran's solid-propellant systems, especially the *Sajjil*, which represents the most significant advance in Iranian missile capabilities to date. Chapter three describes the missile-development programmes of several other countries, against which Iran's programme can be compared and assessed. Using this experience as a point of reference, Chapter four analyses Iran's production capabilities and assesses the types of missiles the nation might try to develop and field in future, and how long it could take for the country to develop new, enhanced capabilities. It also identifies the key, observable trends and indicators of missile development against which Iranian progress can be monitored and appropriate responses planned. Chapter five describes what is known about the size and structure of Iran's missile forces, and how the missiles have been used in the past. It then assesses the military and strategic effectiveness of Iran's potential arsenal, including both conventional and non-conventional warheads. In preparing this dossier, the International Institute for Strategic Studies (IISS) assembled a team of eminent missile experts from the United States, Russia and Western Europe, led by IISS Visiting Senior Fellow for Missile Defence Michael Elleman, Major-General (ret.) Vladimir Dvorkin and Professor Dr Robert Schmucker. Team members presented their preliminary findings at a break-out session of the IISS Global Strategic Review conference in Geneva on 12 September 2009, during which areas for refinement and further research were identified. While there was general consensus on the findings, there were differences of opinion on some of the details, for which the IISS takes responsibility. The Institute's assessment was then sent out for intensive peer review by other missile experts in the US, Russia, Western Europe and the Middle East. Private comments were also sought from various government officials and non-governmental experts. The IISS would like to thank the many individuals who have contributed their knowledge and expertise to the compilation of this dossier. Responsibility for the information and judgements presented here is, unambiguously, the Institute's alone.

Notes

1 Iranian Defence Minister Brigadier-General Ahmad Vahidi said in December 2009, upon the test launching of the *Sajjil*-2 missile, that 'Iran's missile capabilities are strictly defensive and at the service of regional peace and stability. They will never be against any country.' 'Iran Tests New Sejjil-2 Missile With Success', Press TV, 16 December 2010, http://www.presstv.ir/detail.aspx?id=113877.

2 IAEA, 'Implementation of the NPT Safeguards Agreement and Relevant Provisions of Security Council Resolutions 1737 (2006), 1747 (2007), 1803 (2008) and 1835 (2008) in the Islamic Republic of Iran', GOV/2010/10, para 41.

3 Scott D. Sagan, 'The Origins of Military Doctrine and Command and Control Systems', in Peter R. Lavoy, Scott D. Sagan and James J. Wirtz (eds), *Planning the Unthinkable: How New Powers Will Use Nuclear, Biological, and Chemical Weapons* (Ithaca, NY: Cornell University Press, 2000), pp. 36–46.

4 As of April 2010, the US intelligence community had not publicly changed the conclusion of the November 2007 National Intelligence Estimate, which assessed that Iran had halted work on nuclear weapons (but not on fissile-material production) in late 2003 and that work remained frozen until at least mid-2007.

5 'President Bush Speech on Missile Defense at National Defense University', 23 October 2007, available at http://www.missilethreat.com/archives/id.5831/detail.asp.

6 'Executive Summary of the Report of the Commission to Assess the Ballistic Missile Threat to the United States', 15 July 1998, www.fas.org/irp/threat/bm-threat.htm.

7 'Fact Sheet on U.S. Missile Defense Policy: A "Phased, Adaptive Approach" for Missile Defense in Europe', Office of the Press Secretary, White House, 17 September 2009, http://www.whitehouse.gov/the_press_office/FACT-SHEET-US-Missile-Defense-Policy-A-Phased-Adaptive-Approach-for-Missile-Defense-in-Europe/.

8 Under the bilateral 1987 Intermediate-Range Nuclear Forces Treaty, the US and USSR eliminated their ground-launched ballistic and cruise missiles with ranges between 500–5,500km.

9 'India–US Joint Statement', 18 July 2005, available at http://www.dae.gov.in/jtstmt.htm.

10 Robert Joseph and Brendan Melley, 'Proliferation Pact Milestone', *Washington Times*, 28 May 2008. Several PSI interdictions are also documented in Mark J. Valencia, *The Proliferation Security Initiative: Making Waves in Asia*, Adelphi Paper 376 (London: Routledge for the IISS, 2005), pp. 33–8.

11 Wade Boese, 'Interdiction Initiative Successes Assessed', *Arms Control Today*, vol. 38, no. 6, July–August 2008, p. 34.

12 Resolution 1540 (2004), adopted by the Security Council at its 4956th meeting, 28 April 2004, available at http://www.un.org/Docs/sc/unsc_resolutions04.html.

13 'NATO and Russia: A New Beginning', speech by NATO Secretary-General Anders Fogh Rasmussen at the Carnegie Endowment, Brussels, 18 September 2009, http://www.nato.int/cps/en/natolive/opinions_57640.htm.

14 'Iran's Nuclear and Missile Potential: A Joint Threat Assessment by U.S. and Russian Technical Experts', EastWest Institute, May 2009, http://docs.ewi.info/JTA.pdf. See also, Theodore Postol, 'A Technical Assessment of Iran's Ballistic Missile Program; Technical Addendum to the Joint Threat Assessment on Iran's Nuclear and Missile Potential', 6 May 2009, http://docs.ewi.info/JTA_TA_Program.pdf.