HOUSES OF PARLIAMENT
PARLIAMENTARY OFFICE OF SCIENCE & TECHNOLOGY

POSTNOTE

Number 540 October 2016

Nuclear Security

In 2016, the US President stated that the danger of a terrorist group obtaining and using a nuclear weapon was "one of the greatest threats to global security".[1] This briefing provides an overview of the key threats to nuclear security, and of UK and international initiatives that seek to address them.

Overview

- Nuclear security initiatives focus on preventing terrorist groups from carrying out nuclear or radiological attacks.
- The US and Russia own 93% of nuclear warheads and 82% of nuclear material.
- There are 24 countries that have 1 kg or more of weapons-usable nuclear material and over 100 that store radioactive sources.
- Security standards vary widely. Growing cyber threats present a challenge.
- The Nuclear Security Summit process (2010-16) made substantial progress, but gaps remain. The importance of continued focus on this issue is widely recognised.
- Military nuclear materials, which account for 83% of total stockpiles, are not covered by international agreements.

Background

'Nuclear security' refers to the prevention of malicious acts involving nuclear or other radioactive materials and their associated facilities.[2] It is typically used in the context of preventing terrorist groups from perpetrating hostile acts. Nuclear security is distinct from non-proliferation (preventing the spread of nuclear weapons to more countries).

Global concerns over nuclear security date back to the collapse of the USSR in 1991, which left 35,000 nuclear warheads and thousands of tonnes of nuclear material (material that can be used to make a nuclear warhead) spread across Russia, Ukraine, Kazakhstan and Belarus.[3,4] The 9/11 attacks in 2001 also led to speculation about the possibility that terrorists could cause a large release of radioactive material by sabotaging a civil nuclear facility.[5,6]

In recent years, the rise of well-funded terrorist groups, such as Daesh, combined with the spread of civil nuclear power, has placed nuclear security high on the political agenda.[7] There is little reliable evidence in the public domain on the capabilities and intentions of terrorist groups.[8,9,10] However the 2015 Strategic Defence and Security Review reaffirmed, the UK Government's aim to continue "reducing the risk of nuclear material and information falling into the hands of terrorists".[11] In 2016, the then Prime Minister stated that the issue of nuclear security was "absolutely vital".[12]

There have been several global initiatives to improve nuclear security (Box 1), including the Nuclear Security Summit (NSS) process (2010-16).[13] However, analysis by the Nuclear Threat Initiative (NTI),[14] a US NGO, suggests that progress on nuclear security has slowed since 2014.[15] This POSTnote outlines key threats to nuclear security and approaches to address them, covering:

- detonation of a nuclear device by terrorists (i.e. acquisition or construction of a nuclear warhead),
- radiological attack (dispersal of radioactive material) by terrorists, for example by sabotage of a civilian nuclear facility or using a radiological dispersal device,
- international policy challenges such as continuing the progress made by the NSS process.

Detonation of a Nuclear Device

A terrorist group seeking to detonate a nuclear device might try to obtain a warhead from a nuclear-armed state (most likely by theft) or build its own using stolen materials. Of the scenarios discussed in this paper, the consequences of a nuclear detonation would be the most severe (Box 2).

Acquisition of a Nuclear Warhead

Although there is little information in the public domain, defence analysts suggest that nuclear warheads are well protected because they form an important part of the national security of the countries that own them.[16,17]

Box 1. International Nuclear Security Agreements and Processes

Cooperative Initiatives

Non-binding bilateral and multilateral agreements play an important role in strengthening nuclear security. Key initiatives include:

- The Global Partnership Against the Spread of Weapons and Material of Mass Destruction (2002-present, 29 member states), which coordinates international assistance to improve nuclear and radiological as well as chemical and biological security.[18]
- The Global Initiative to Combat Nuclear Terrorism (2006-present, 86 member states) which provides technical assistance, through workshops and other events, to help tackle nuclear terrorism.[19]

Legally-Binding International Agreements[20]

- UN Security Council Resolution 1540 (adopted 2004) obliges member states to develop and enforce legislation to prevent the spread of WMD to non-state actors (e.g. terrorists).[21]
- International Convention on the Suppression of Acts of Nuclear Terrorism (ICSANT, came into force 2007) requires that states criminalise and punish acts of nuclear terrorism.[22]
- Amendment to the Convention on the Physical Protection of Nuclear Materials (CPPNM/A, came into force 2016) obliges states to protect their civilian nuclear material and facilities.[23]

Nuclear Security Summit (NSS) Process (2010-16)

The NSS process consisted of four head of government level summits organised by the US Government. Its key achievements include the removal of almost 3 tonnes of weapons-usable nuclear material from 27 countries and the ratification the CPPNM/A by 26 countries.[24,25]

Protection measures typically include multiple physical barriers and armed guards. Modern nuclear warheads are also protected against unauthorised use by electronic security codes.[26,27,28] However, standards vary globally.[29,30]

There are currently roughly 15,500 nuclear warheads owned by 9 countries.[31,32] The majority are owned by the US (46%) and Russia (47%). The UK has 215 warheads but plans to reduce this to 180 warheads by the mid-2020s. Global stockpiles have fallen by 68% since 1991, largely due to US and Russian reductions.[33] However, China, Israel,[34] India, Pakistan and North Korea continue to expand their nuclear arsenals.[35,36] Tactical nuclear warheads designed for battlefield use account for around 16% of the total stockpile (2,550 warheads).[37] Most are owned by the US (20%) and Russia (78%), with the remainder in France and China.[38] The US stores around 200 tactical warheads at its bases in Belgium, Germany, Italy, the Netherlands and Turkey.[39] Pakistan is thought to be developing tactical warheads.[31,40]

Academic literature focuses mainly on the security of nuclear warheads owned by Russia, thought to be stored at 40 different sites, and Pakistan, which faces a threat from well organised terrorist groups.[41,42,43] Tactical warheads, which are smaller and more portable, are thought to be at greater risk of theft.[44,45] Overall, the likelihood of a warhead being stolen by a terrorist group is considered low relative to the other types of attack discussed here, although robust threat assessments are not publically available.[46,47,48,49]

Construction of a Nuclear Device

There are two broad types of nuclear device: gun-type and implosion-type. The former are relatively crude and can be made using highly enriched uranium (HEU).[50]

Box 2. Consequences of a Nuclear or Radiological Attack

The impact of a nuclear or radiological attack would depend on many factors including weather conditions, local geography, population density and the effectiveness of emergency planning and services.[5]

Detonation of a Nuclear Device

The energy released by the detonation of a nuclear device (the yield) varies widely depending on several factors such as design or efficiency of detonation.[51] Detonation in a populated area would cause large-scale destruction and loss of life. For example, the Hiroshima bomb killed around 70,000 people instantly.[52]

Radiological Attack

The amount of radioactive material released by a radiological dispersal device (RDD) might be very small but the RDD could still have considerable social and economic impact.[5,53] A large-scale radiological release resulting from the sabotage of a nuclear facility, although difficult to bring about (page 3), could in addition have major health and environmental impacts. For example, the releases that occurred during the Chernobyl and Fukushima accidents are each estimated to have cost more than $200 billion and have resulted in exclusion zones of 30 km and 20 km respectively.[54,55,56]

The latter are sophisticated devices made using either HEU or separated plutonium (SP).[50] HEU and SP are described as weapons-usable nuclear materials (WUNMs). While most analysts believe a well-funded terrorist group could manufacture a gun-type device with limited yield (Box 2), there is debate over whether terrorists would have the technical expertise to make an implosion-type device.[57,58,59]

HEU is produced by ‘enriching’ natural uranium or low enriched uranium (LEU). This requires large amounts of energy and high quality separation equipment.[50,60] SP is extracted from used nuclear reactor fuel by ‘reprocessing’, a process that requires a large chemical plant and specialist equipment.[50] Defence analysts think it unlikely that a terrorist group would have the resources to produce their own WUNM and would look to existing stockpiles (Box 3).

Securing Weapons Usable Nuclear Materials (WUNMs)

Preventing terrorists from obtaining WUNM is the most effective way of stopping them obtaining a nuclear device.[7] Minimising, consolidating and securing WUNM are all ways of doing this.[7] Minimisation efforts have included down-blending HEU (mixing it with natural uranium) so it is no longer usable in a nuclear device.[61] Between 1993 and 2013, the US-Russia HEU Purchase Agreement resulted in the downblending of 500 tonnes of HEU.[62] Consolidation efforts have focused on repatriating US and Russian-origin HEU. Since the NSS process began, the number of countries with >1 kg of WUNM has fallen from 35 to 24. Converting HEU fuelled reactors to use LEU and replacing HEU with LEU in medical isotope production have helped achieve further reductions.[61,63]

Countries that own civilian stockpiles of WUNM are legally obliged to protect them (Box 1).[23] The International Atomic Energy Agency (IAEA, Box 4) provides guidance on how a state can secure its civil nuclear material to meet legal requirements.[64] These include multiple physical barriers, extensive monitoring and armed guards. They also include searching of personnel, vehicles and packages entering or

Box 3. Obtaining Weapons Usable Nuclear Materials (WUNMs)
The amount of HEU needed to make a nuclear warhead depends on its 'enrichment', or the percentage of U-235 (the form of uranium required for a nuclear explosion) it contains. By definition, HEU is enriched to at least 20%.[2] Generally, the higher the enrichment the less HEU is needed. A gun-type device would require at least 40-50 kg of 90% enriched HEU. An implosion type device would require at least 15 kg of 90% enriched HEU or 8 kg of separated plutonium.[60]

Highly Enriched Uranium (HEU) Stockpile
The International Panel on Fissile Material (IPFM) estimates that there are around 1,370 tonnes of HEU globally.[50] Around 92% is used in nuclear warheads and naval fuel, and 8% in the civilian sector. Civilian HEU is used in research reactors and to produce isotopes for medical and industrial purposes. Russia uses HEU to fuel civilian ice breakers. Most of the global HEU stockpile is held by the US (39%) and Russia (54%). HEU stockpiles have fallen by ~34% since 1991.[61] India and Pakistan still produce HEU for their nuclear weapons programs.[50]

Separated Plutonium (SP) Stockpile
The IPFM estimates that the global stockpile of SP is 505 tonnes, 72% of which is civilian SP.[50] Since 1991, global stockpiles have increased by 40% as reductions in military SP have been offset by increases due to civilian reprocessing. The majority of civilian SP is held by the UK (44%), France (26%) and Russia (22%), with Japan (5%) and Germany (1%) owning smaller amounts. Decisions on management of the large British and French civilian SP stockpiles are still being made.[65] Further information on the UK's SP stockpile can be found in POSTnote 531. India, Pakistan, Israel and North Korea continue to produce SP for their nuclear weapons programs.[50]

exiting sites. Accounting measures, such as IAEA safeguards (Box 4), can detect the theft of civil WUNM. Some reports suggest that more robust accounting measures may be needed to detect theft effectively. Moreover, there could be a time lag between theft and detection.[66,67] The NTI ranks the security measures taken by countries to prevent the theft of WUNM in its Nuclear Security Index (Box 5).[14]

Cyber Interference with a Nuclear Weapon
Defence analysts think that it would be extremely difficult for a terrorist group to hack into a nuclear command and control system.[68] However, terrorists might be able to use less sophisticated means to exacerbate a crisis between nuclear-armed states by interfering with communications.[69] Countries that keep warheads on high alert are thought to be more susceptible to such attacks.[70,71] The Federation of American Scientists estimates that 920 US and 890 Russian warheads are kept on high-alert.[72] Other countries are believed to keep their warheads at lower alert levels.[72]

Radiological Attack
Terrorists seeking to cause a release of radioactive material might try to sabotage a nuclear facility, or set off a radiological dispersal device. The consequences would vary depending on factors such as the size and nature of any release and the efficiency of emergency planning (Box 2).

Sabotage of Nuclear Facilities
Facilities requiring protection against sabotage include reactor buildings and storage facilities for other radioactive materials, such as used reactor fuel, as well as vital support systems, such as cooling systems.[5] There are 450 nuclear

Box 4. The Role of the International Atomic Energy Agency
The IAEA promotes the safe, secure and peaceful use of nuclear energy. As part of this, it plays a key role in helping states protect their civilian nuclear materials and facilities.[73] It uses safeguards to check that civil nuclear material is not being diverted into military programmes[74] and supports states by providing assistance such as:
- publishing recommendations and technical guidelines, such as the Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities, which helps states comply with the 2005 Amendment to the Convention on the Physical Protection of Nuclear Material;[64]
- undertaking and organising advisory security assessment and peer-review missions through its International Physical Protection Advisory Service and International Nuclear Security Service.[75]

reactors in operation in 31 countries. A further 60 are under construction, including 37 in Asia.[76] Nuclear facilities are designed with safety provisions such as thick concrete shielding, steel containment and redundancies (independent and diverse systems providing multiple backups in an emergency). These provide some protection against terrorist attack. However, 85% of nuclear reactors were built before the 9/11 attacks and were not designed with sabotage in mind. Many have since been retrofitted to increase their resilience.

International legislation obliges states to protect civilian nuclear facilities against sabotage (Box 1). The NTI ranks measures taken by countries to reduce the risk of sabotage in its Nuclear Security Index (Box 5). Its 2016 index found that many developing countries considering nuclear energy programs lack adequate protection against sabotage.[14]

Particular attention has been focused on the threat from cyber-attacks (Box 6) and from insiders working at nuclear facilities.[77,78] Efforts to tackle the insider threat include improving vetting procedures by increasing continuous monitoring, and changing protocols to require at least two authorised operators to access sensitive areas.[7] Some argue that the complexity of the nuclear supply chain could introduce further vulnerabilities, including cyber-attacks.

UK Nuclear Facilities
There are 8 nuclear power stations in the UK operating 15 reactors[76] with plans to build 13 new reactors at 5 sites.[79] There are 11 further civil nuclear sites including enrichment and reprocessing facilities and waste disposal sites. Seven licensed military nuclear sites support the UK's nuclear weapons and submarines.[80] The Office of Nuclear Regulation (ONR) is responsible for regulating safety and security at the UK's civil nuclear sites.[80] In recent years, efforts have focused on improving physical protection measures and the cybersecurity of command and control systems, with particular emphasis on legacy buildings that house large quantities of radioactive material.[81] The UK's largest civil nuclear site at Sellafield in Cumbria is one of the ONR's key priorities.[82] The Sellafield Security, Emergency Management and Resilience Programme aims to deliver a range of security upgrades. However, a shortage of skilled personnel is an issue for both ONR and for site operators.

Box 5. Nuclear Security Index

The Nuclear Security Index is a set of rankings developed by the Nuclear Threat Initiative (NTI).[14] The index ranks countries based on a range of nuclear security measures by analysing factors such as government policy and regulation. It does not conduct direct observations of security measures at individual sites. In 2016, the NTI incorporated a cybersecurity indicator into each of its rankings.[14]

Theft Index (24 countries with weapons-usable nuclear material)

Australia came 1st (the best score) in the theft ranking for countries with weapons-usable nuclear material (WUNM). The UK ranked joint 11th, one place below the US, due to its large stockpile of civilian SP. India (21st) and Pakistan (22nd) performed particularly poorly as both countries have gaps in their regulatory frameworks and both have increased their stockpiles of WUNMs.

Sabotage Index (44 countries with civilian nuclear programmes)

Finland achieved the best score, while the UK ranked joint 3rd, three places above the US. The UK was one of 13 countries to achieve the maximum score for cybersecurity although its high number of nuclear facilities had a negative impact on its score. India and Pakistan (joint 36th) performed poorly, in part due to a lack of transparency.

Radiological Dispersal Device (RDD)

An RDD is any device that disperses radioactive material. There are several ways in which radioactive material can be dispersed, including using conventional explosives. Many analysts point out that RDDs are the most technically straightforward of the scenarios discussed in this briefing.[83]

Radioactive materials are stored at numerous sites in over 100 countries. Following the 2014 NSS, 23 countries agreed to increase the security of their most dangerous radioactive materials.[84,85] Efforts have focussed on the security of: caesium and cobalt (medical applications); iridium, americium and beryllium (industrial applications) and plutonium (found in nuclear waste), because of their radioactivity and widespread availability. Security standards vary widely and a recent NTI report suggests that although security measures have improved, significant gaps remain.[84]

International Policy Challenges

Nuclear Security Summit: What Happens Next?

The NSS process (Box 1) concluded in 2016. Foreign policy experts have emphasised the importance of continuing the international dialogue between government ministers and officials on nuclear security issues.[7,86] Defence analysts suggest that the IAEA should take a more prominent role in strengthening civil nuclear security.[86] While the NSS process focussed on civilian WUNM, military WUNM accounts for around 83% of the global stockpile. It is not covered by current agreements or confidence building measures.[87] The NTI suggests that stronger security and accounting measures are required to reduce the risk posed by military WUNM.[87] However, analysts point out that achieving multilateral agreement in this area is challenging, given sensitivities over information sharing.

US-Russia relationship

Historically, US-Russian cooperation has been an important part of improving nuclear security. Key examples include the 1992 Cooperative Threat Reduction program and the 1993 HEU Purchase Agreement.[62,91,92] However, following its annexation of Crimea in 2014, Russia was expelled from the G8 and withdrew from the 2016 NSS.[93] While the scale of US-Russian collaboration has decreased, foreign policy experts highlight that Russia continues to take part in nuclear security initiatives, including the Global Initiative to Combat Nuclear Terrorism (Box 1), which it co-chairs.[93] However concerns have been raised over the recent suspension of bilateral agreements relating to WUNM.[94,95]

Box 6. Improving Cybersecurity of Civil Nuclear Facilities

Due to strict regulatory requirements, the civil nuclear sector has been relatively slow to adopt digital systems compared to other types of critical infrastructure. A recent Chatham House report highlighted several ways to improve the cybersecurity of nuclear facilities.[88]

- Assessing the risks posed by cyber-attacks would help plant operators allocate appropriate resources to improve cybersecurity.
- Developing a strong cybersecurity culture is key to defending against cyber-attacks. This includes changing passwords regularly and avoiding unnecessary internet connections.
- Sharing information about cyber threats across the industrial sector is an important part of cyber defence, as attacks often exploit common vulnerabilities. In the UK, the Cyber-security Information Sharing Partnership, part of the Computer Emergency Response Team, provides a platform for cybersecurity collaboration.
- Enhancing the security of control systems by adding authentication and verification steps could provide extra layers of defence. Increasing their physical isolation from unsecure networks such as the internet (air-gapping), would also help improve cybersecurity.[89]
- Improving information security is an important part of preventing terrorists from obtaining vital information about the digital control systems used at a nuclear facility.[90]

Funding Nuclear Security Projects

The IAEA funds nuclear security activities from its regular budget and its Nuclear Security Fund (NSF), which is dependent on voluntary contributions, mainly from the US, EU and UK.[96,97] Recent reports highlight that the IAEA's reliance on the NSF affects the planning and prioritisation of its nuclear security projects.[98,99] Some policy analysts have suggested alternative funding models.[7] The UK funds nuclear security projects through its Global Threat Reduction Programme. From 2011 to 2016, the UK provided £62.8 million of funding for a range of projects.[100,101]

Endnotes

1 President Barack Obama (01/04/2016). Remarks by President Obama and Prime Minister Rutte at Opening Session of the Nuclear Security Summit. 2016 Nuclear Security Summit.
2 International Atomic Energy Agency (2016). Safety Glossary: Terminology used in Nuclear Safety and Radiation Protection. 2016 Revision.
3 Graham Allison (03/2012). What Happened to the Soviet Superpower's Nuclear Arsenal? Belfer Center, Harvard University.
4 Carol E. Kessler (2013). The Fall of the Soviet Union and the Rise of Nuclear Security. MIT Laboratory for Nuclear Security and Policy Seminar.
5 Chandrika Nath (07/2004). Assessing the risk of terrorist attacks on nuclear facilities. Parliamentary Office of Science and Technology. POST Report 222. Houses of Parliament.
6 Mark Holt and Anthony Andrews (08/08/2007). Nuclear Power Plants: Vulnerability to Terrorist Attack. Congressional Research Service Report RS21131. United States Congress.
7 Matthew Bunn, Martin B. Malin, Nickolas Roth and William H. Tobey (03/2016). Preventing Nuclear Terrorism Continuous Improvement or Dangerous Decline? Belfer Center, Harvard University.

POST is an office of both Houses of Parliament, charged with providing independent and balanced analysis of policy issues that have a basis in science and technology. POST is grateful to Akshay Deshmukh for researching this briefing, to the Institution of Chemical Engineers and the Northeast of England Process Industry Cluster for funding his parliamentary fellowship, and to all contributors and reviewers. For further information on this subject, please contact the co-author, Dr Chandrika Nath.

8 Rolf Mowatt-Larssen (01/2010). Al Qaeda Weapons of Mass Destruction Threat: Hype or Reality? A Timeline of Terrorists' Efforts to Acquire WMD. Belfer Center, Harvard University.
9 Central Intelligence Agency (18/03/1997). Excerpts from: Usama Bin Ladin's Attempts to Acquire Uranium.
10 Janes Terrorism & Security Monitor (12/02/2004). Is Al-Qaeda Receiving Nuclear Help? Jane's Intelligence Review. Terrorism & Security Monitor.
11 HM Government (11/2015). National Security Strategy and Strategic Defence and Security Review 2015: A Secure and Prosperous United Kingdom.
12 David Cameron (31/03/2016). David Cameron & François Hollande Reflect on the Nuclear Security Summit. The White House Photos and Videos.
13 Wyn Bowen, Matthew Cottee, Chris Hobbs, Luca Lentini and Matthew Moran (2016). Nuclear Security Summit Briefing Book: 2016 Edition. Centre for Science and Security Studies, King's College London.
14 Page Stoutland and Samantha Pitts-Kiefer (14/01/2016). Nuclear Security Index 2016: Building a Framework for Assurance, Accountability, and Action. 3rd Edition. Nuclear Threat Initiative and Economist Intelligence Unit.
15 Joan Rohlfing, Samantha Pitts-Kiefer, and Andrew J. Bieniawski (03/2016). Global Dialogue on Nuclear Security Priorities: Building an Effective Global Nuclear Security System. Nuclear Threat Initiative.
16 Matthew Cottee and Dina Esfandiary (15/10/2014). The very small Islamic State WMD threat. The Bulletin of the Atomic Scientists Analysis Feature.
17 Christoph Wirz & Emmanuel Egger (30/09/2005). Use of nuclear and radiological weapons by terrorists? International Review of the Red Cross, Volume 87 Number 859.
18 Nuclear Threat Initiative (23/06/2013). Global Partnership Against the Spread of Weapons and Materials of Mass Destruction.
19 Global Initiative to Combat Nuclear Terrorism (06/2016). Global Initiative to Combat Nuclear Terrorism Fact Sheet.
20 International Atomic Energy Agency (2011). The International Legal Framework for Nuclear Security. International Atomic Energy Agency International Law Series No. 4.
21 United Nations Security Council Resolution 1540 (24/04/2004).
22 United Nations (13/04/2005). International Convention for the Suppression of Acts of Nuclear Terrorism. Annex to General Assembly resolution 59/290 of 13 April 2005.
23 International Atomic Energy Agency (09/05/2016). Amendment to the Convention on the Physical Protection of Nuclear Material. INFCIRC/274/Rev.1/Mod.1.
24 Michelle Cann, Kelsey Davenport and Jenna Parker (03/2016). The Nuclear Security Summit: Accomplishments of the Process. Arms Control Association and Partnership for Global Security.
25 Foreign and Commonwealth Office (01/04/2016). Nuclear Security Summit 2016 Policy Paper. HM Government.
26 American Association for the Advancement of Science and the Union of Concerned Scientists (11/2013). Summary Report on the Workshop on U.S. Nuclear Weapons Safety and Security.
27 Ross J. Anderson (04/2008). Security Engineering: A Guide to Building Dependable Distributed Systems, 2nd Edition. Chapter 11: Nuclear Command and Control, Section 11.5 Tamper Resistance and PALs.
28 Steven Bellovin (22/01/2015). Permissive Action Links. Department of Computer Science. Columbia University.
29 Paul K. Kerr and Mary Beth Nikitin (10/05/2012). Pakistan's Nuclear Weapons: Proliferation and Security Issues. Congressional Research Service Report RL34248. United States Congress.
30 Jonathan Medalia (10/02/2005). Nuclear Terrorism: A Brief Review of Threats and Responses. Congressional Research Service Report RL32595. United fStates Congress.
31 Claire Mills and Jon Lunn (29/06/2016). Nuclear Weapons – Country Comparisons. House of Commons Library: Commons Briefing papers CBP-7566.
32 Arms Control Association (10/2015). Nuclear Weapons: Who Has What at a Glance.
33 Hans M. Kristensen & Robert S. Norris (2013) Global nuclear weapons inventories, 1945–2013. Bulletin of the Atomic Scientists, 69:5, 75-81.
34 Since the 1960s, the Israeli Government has maintained a policy of official ambiguity on the issue of nuclear weapons. It has never confirmed or denied having nuclear weapons. Despite this, it is universally acknowledged that Israel possesses nuclear weapons.[31]
35 Robert S. Norris and Hans M. Kristensen (2012). Nuclear pursuits, 2012. Bulletin of the Atomic Scientists, 68:1, 94-98.
36 David Blagden (03/2015). Global Multipolarity, European Security and Implications for UK Grand Strategy: Back to the Future, Once Again. International Affairs 91:2 pp. 333-350.
37 Hans M. Kristensen (05/2012). Non-Strategic Nuclear Weapons. Federation of American Scientists.
38 Hans M. Kristensen & Robert S. Norris (2014). Slowing nuclear weapon reductions and endless nuclear weapon modernizations: A challenge to the NPT. Bulletin of the Atomic Scientists, 70:4, 94-107.
39 Robert S. Norris & Hans M. Kristensen (2011). US tactical nuclear weapons in Europe, 2011. Bulletin of the Atomic Scientists, 67:1, 64-73.
40 Hans M. Kristensen & Robert S. Norris (2012) Nonstrategic nuclear weapons, 2012. Bulletin of the Atomic Scientists, 68:5, 96-104.
41 Michael Jasinski (01/04/2001). The Security and Safety of Russia's Nuclear Weapons. Nuclear Threat Initiative.
42 Brian Cloughley (18/03/2011). Fission fears Pakistan's nuclear security under scrutiny. Jane's Intelligence Review. Proliferation and Procurement.
43 Paul K. Kerr and Mary Beth Nikitin (01/08/2016). Pakistan's Nuclear Weapons. Congressional Research Service Report RL34248. United States Congress.
44 Amy F. Woolf (23/03/2016). Nonstrategic Nuclear Weapons. Congressional Research Service Report RL32572. United States Congress.
45 Nikolai Sokov (01/05/2002). Tactical Nuclear Weapons (TNW): The Dangers Associated with TNWs. Nuclear Threat Initiative.
46 Charles P. Blair (2011). Fatwas for fission: Assessing the terrorist threat to Pakistan's nuclear assets. Bulletin of the Atomic Scientists, 67:6, 19-33.
47 Leonard Weiss (27/11/2015). On fear and nuclear terrorism. Bulletin of the Atomic Scientists, 71:2, 75-87.
48 Nada Eweiss (03/2016). Non-state actors & WMD: Does ISIS have a pathway to a nuclear weapon?. British American Security Information Council.
49 Rolf Mowatt-Larssen (2010). Nightmares of Nuclear Terrorism. Bulletin of the Atomic Scientists, 66:2, 37-45.
50 International Panel on Fissile Materials (2015). Global Fissile Material Report 2015: Nuclear Weapon and Fissile Material Stockpiles and Production.
51 Hans M. Kristensen & Robert S. Norris (2016). United States nuclear forces, 2016. Bulletin of the Atomic Scientists, 72:2, 63-73.
52 US Strategic Bombing Survey (19/06/1946). The Effects of the Atomic Bombings of Hiroshima and Nagasaki. Truman Papers, President's Secretary's File.
53 Chatham House (2016). Use of Chemical, Biological, Radiological and Nuclear Weapons by Non-State Actors: Emerging trends and risk factors. Lloyd's Emerging Risk Report.
54 The Chernobyl Forum: 2003—2005 (2006). Chernobyl's Legacy: Health, Environmental and Socio-economic Impacts and Recommendations to the Governments of Belarus, the Russian Federation and Ukraine. International Atomic Energy Agency.
55 Prachi Patel (11/102011). Three Mile Island, Chernobyl, and Fukushima: A comparison of three nuclear reactor calamities reveals some key differences. Institute of Electrical and Electronics Engineers.
56 Belarus Foreign Ministry (04/2009). Chernobyl disaster: Why are the consequences still observed? And Why is the international assistance still critical? Belarus Government.
57 Matthew Bunn and Anthony Wier (09/2006). Terrorist Nuclear Weapon Construction: How Difficult? The Annals of the American Academy of Political and Social Science, Vol. 607, Confronting the Specter of Nuclear Terrorism pp. 133-149.
58 Laurence Silberman and Charles Robb (31/03/2005). The Commission on the Intelligence Capabilities of the United States Regarding Weapons of Mass Destruction. Report to the President of the United States.
59 J. Carson Mark et al (1977). Nuclear Proliferation and Safeguards. United States Office of Technology Assessment, Task Force on Nuclear Weapons. United States Government.
60 Union of Concerned Scientists (04/2004). Preventing Nuclear Terrorism: Fissile Material Fact Sheet.
61 Frank von Hippel (15/03/2016). Banning the production of highly enriched uranium. International Panel on Fissile Materials.
62 Bill Wanderer (13/05/2014). U.S.-Russia Highly Enriched Uranium (HEU) Purchase Agreement Update Presentation. Office of Nuclear Verification, National Nuclear Security Administration, US Department of Energy.
63 Corey Hinderstein, Andrew Newman & Ole Reistad (2012). From HEU minimization to elimination: Time to change the vocabulary. Bulletin of the Atomic Scientists, 68:4, 83-95.
64 International Atomic Energy Agency (2011). Nuclear Security Recommendations on Physical Protection of Nuclear Material and Nuclear Facilities (INFCIRC/225/Revision 5). IAEA Nuclear Security Series No. 13. Recommendations.
65 Managing the UK's Plutonium Stockpile. POSTnote 531, 2016. Parliamentary Office of Science and Technology, Houses of Parliament.
66 Charles D. Ferguson (2008). Strengthening Nuclear Safeguards. Issues in Science and Technology.

67 Jonas Siegel, John Steinbruner, and Nancy Gallagher (03/2014). Comprehensive nuclear material accounting: A proposal to reduce global nuclear risk. Center for International and Security Studies. University of Maryland.
68 Andrew Futter (2015). Hacking the bomb: nuclear weapons in the cyber age. Paper presented at the International Studies Annual Conference, 23–27 February, New Orleans.
69 Andrew Futter (211/10/2015). War Games redux? Cyberthreats, US–Russian strategic stability, and new challenges for nuclear security and arms control. European Security Volume 25, Issue 2.
70 Global Zero Commission on Nuclear Risk Reduction (04/2015). De-Alerting and Stabilizing the World's Nuclear Force Postures.
71 David Wright, Eryn MacDonald and Lisbeth Gronlund (2016). Reducing the Risk of Nuclear War. Union of Concerned Scientists.
72 Hans M. Kristensen and Matthew McKinzie (2012). Reducing Alert Rates of Nuclear Weapons. United Nations Institute for Disarmament Research.
73 Trevor Findlay (06/2013). Discussion Paper: The IAEA's Nuclear Security Role. Nuclear Threat Initiative.
74 International Atomic Energy Agency (06/2015). IAEA Safeguards: Serving Nuclear Non-Proliferation.
75 International Atomic Energy Agency (02/08/2013). Nuclear Security Plan for 2014-2017. GOV/2013/42-GC(57)/19.
76 International Atomic Energy Agency (03/07/2016). The Database on Nuclear Reactors. Power Reactor Information System (PRIS).
77 George Chamales (01/06/2015). A New Approach to Nuclear Computer Security. Nuclear Threat Initiative.
78 Office of the Press Secretary (01/04/2016). Nuclear Security Summit 2016: Gift Basket on Mitigating Insider Threats. The White House.
79 World Nuclear Association (07/2016). Nuclear Power in the United Kingdom: Power reactors planned and proposed.
80 Office for Nuclear Regulation (10/2014). A guide to Nuclear Regulation in the UK.
81 Office for Nuclear Regulation (03/2016). Office for Nuclear Regulation Strategic Plan 2016—2020.
82 Nuclear Decommissioning Authority (06/05/2016).Priority Programmes and Major Projects Performance Report (data as at end September 2015). Ref: 24102622 (Version 10.0).
83 Elisabeth Eaves (07/04/2016). What does "nuclear terrorism" really mean? Bulletin of the Atomic Scientist News.
84 Andrew J. Bieniawski, Ioanna Iliopulos and Michelle Nalabandian (23/03/2016). Radiological Security Progress Report. Nuclear Threat Initiative.
85 Nuclear Security Summit 2016 (11/03/2016). Joint Statement on the Security of High Activity Radioactive Sources. Gift basket sponsored by France.
86 Trevor Findlay (11/03/2014). Beyond Nuclear Summitry: The Role of the IAEA in Nuclear Security Diplomacy After 2016. Belfer Center, Harvard University.
87 Andrew Bieniawski, Des Browne, Richard G. Lugar, Sam Nunn (10/11/2015). Bridging the Military Nuclear Materials Gap. Nuclear Threat Initiative.
88 Caroline Baylon, Roger Brunt and David Livingstone (11/2015). Cyber Security at Civil Nuclear Facilities, Understanding the Risks. Chatham House, the Royal Institute of International Affairs.
89 HM Government and PA Consulting Group (2015). Security for Industrial Control System Framework Overview: A Good Practice Guide. Input from Communications Electronics Security Group (part of Government Communications Headquarters) and Centre for the Protection of National Infrastructure.
90 International Atomic Energy Agency (2015). Security of Nuclear Information. IAEA Nuclear Security Series No. 23-G Implementing Guide.
91 Joseph P. Harahan (2014). With Courage and Persistence: Eliminating and Securing Weapons of Mass Destruction with the Nunn-Lugar Cooperative Threat Reduction Programs. Defense Threat Reduction Agency, US Department of Defense.
92 Mary Kaszynski (25/07/2012). The Nunn-Lugar Cooperative Threat Reduction Program. American Security Project Factsheet.
93 Matthew Cottee (19/11/2015). IISS Voices: Ways forward for nuclear security. International Institute for Strategic Studies.
94 Alexey Arbatov (17/10/2016). The Ominous End of the Russia-U.S. Plutonium Agreement. Carnegie Endowment: Moscow Center.
95 Frank Klotz (12/10/2016). The Legacy of President Obama's Nuclear Security and Non-Proliferation Agenda Discussion Meeting. International Institute for Strategic Studies.
96 Giovanni Verlini (19/11/2010). EU Renews Financial Support to Nuclear Security Fund. Division of Public Information, International Atomic Energy Agency.
97 Nuclear Security Summit 2016 (31/03/2016). National Progress Report: United Kingdom.
98 International Atomic Energy Agency (06/08/2013). Nuclear Security Report 2013. Board of Governors General Conference, GOV/2013/36-GC(57)/16.
99International Atomic Energy Agency (22/07/2014). Nuclear Security Report 2014. Board of Governors General Conference, GOV/2014/36-GC(58)/14.
100Department of Energy and Climate Change (03/2011). Global Threat Reduction Programme: Eighth Annual Report 2010. Foreign and Commonwealth Office, Department of Energy and Climate Change and Ministry of Defence, UK Government.
101Department of Energy and Climate Change (30/10/2015). UK International Chemical, Biological, Radiological and Nuclear Security Assistance Programmes and their Contribution to the Global Partnership Against the Spread of Weapons and Materials of Mass Destruction. UK Government.