Appendix 8B. Nuclear explosions, 1945–2009

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I. Introduction

In May 2009 the Democratic People's Republic of Korea (DPRK, or North Korea) conducted what is widely believed to be a nuclear test explosion. This was North Korea's second nuclear explosion, following one conducted in October 2006, and brought the total number of nuclear explosions recorded since 1945 to 2054. This appendix describes the available information on the North Korean explosion and then presents up-to-date data on the number of nuclear explosions conducted since 1945.[1]

II. The nuclear test in North Korea

On 29 April 2009 North Korea's official news agency, the Korean Central News Agency (KCNA), issued a statement warning that the country was prepared to conduct a nuclear test explosion as a response to the imposition of sanctions by the United Nations Security Council.[2] On 25 May 2009 the Chinese and United States governments were reportedly given less than one hour's notice that North Korea would conduct a nuclear test.[3] The explosion itself took place at 00:54 UTC.[4] At 02:24 UTC the International Monitoring System (IMS) of the Comprehensive Nuclear-Test-Ban Treaty Organization Preparatory Commission (CTBTO) issued the first report to CTBTO member states on the time, location and magnitude of the event.[5] A few hours later the KCNA announced that North Korea had conducted 'one more successful underground nuclear test' that was 'on a new higher level in terms of its explosive power and technology'.[6]

The KCNA claim had to be verified by available technologies. The technologies used for verification of underground nuclear tests include seismology,

[1] For full details of how international researchers have sought to determine the explosion's nature, location and yield based on the available data see Fedchenko, V., 'North Korea's nuclear test explosion, 2009', SIPRI Fact Sheet, Dec. 2009, <http://books.sipri.org/product_info?c_product_id=397>.

[2] 'UNSC urged to retract anti-DPRK steps', Korean Central News Agency, 29 Apr. 2009, <http://www.kcna.co.jp/item/2009/200904/news29/20090429-14ee.html>. For further background see chapter 9, section IV, in this volume.

[3] 'NKorea informed US of nuclear test: official', Agence France-Presse, 25 May 2009, <http://www.google.com/hostednews/afp/article/ALeqM5gRTYYuI6qR20V2-SERacQVXo4Zhg>.

[4] UTC is Coordinated Universal Time, which approximates to Greenwich Mean Time (GMT).

[5] CTBTO, 'CTBTO's initial findings on the DPRK's 2009 announced nuclear test', Press release, 25 May 2009, <http://www.ctbto.org/press-centre/press-releases/2009/ctbtos-initial-findings-on-the-dprks-2009-announced-nuclear-test/>.

[6] 'KCNA report on one more successful underground nuclear test', Korean Central News Agency, 25 May 2009, <http://www.kcna.co.jp/item/2009/200905/news25/20090525-12ee.html>.

Table 8B.1. Data on North Korea's nuclear explosion, 25 May 2009

Source[a]	Origin time (UTC)	Latitude	Longitude	Error margin[b]	Body wave magnitude[c]
IDC, Vienna[d]	00:54:42.8	41.3110° N	129.0464° E	±9.6 km[e]	4.52
BJI, Beijing	00:54:43.10	41.3000° N	129.0000° E	. .	4.6
CEME, Obninsk	00:54:40.9	41.29° N	129.07° E	. .	5.0
NEIC, Denver	00:54:43	41.306° N	129.029° E	±3.8 km[f]	4.7
NORSAR, Karasjok	00:54:43	41.28° N	129.07° E	. .	4.7

UTC = Coordinated Universal Time; km = kilometres; . . = data not available.

[a] Because of differences between estimates, particularly regarding the precise site of the explosion, data from 5 sources—1 internationally recognized body and 4 national bodies—is provided for comparison: IDC = Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), International Data Centre, Vienna; BJI = China Earthquake Administration, Institute of Geophysics, Beijing; CEME = Russian Academy of Sciences, Geophysical Survey, Central Experimental Methodical Expedition, Obninsk, Kaluga oblast; NEIC = US Geological Survey, National Earthquake Information Center, Denver, CO; NORSAR = Norwegian national data centre for the CTBTO, Karasjok.

[b] The error margins are as defined by the data sources.

[c] Body wave magnitude indicates the size of the event. In order to give a reasonably correct estimate of the yield of an underground explosion, detailed information is needed (e.g. on the geological conditions in the area where the explosion took place). Body wave magnitude is therefore an unambiguous way of giving the size of an explosion.

[d] The IDC was 'in a test and provisional operation mode only' and only 75% of the monitoring stations in the CTBTO's International Monitoring System were contributing data at the time of the event.

[e] This figure is the length of the semi-major axis of the confidence ellipse.

[f] This figure is the horizontal location error, defined as the 'length of the largest projection of the three principal errors on a horizontal plane'.

Sources: *IDC data*: Excerpts from the CTBTO Reviewed Event Bulletin (REB) provided by the CTBTO Public Information Section and the Swedish Defence Research Agency (FOI); and CTBTO, 'CTBTO's initial findings on the DPRK's 2009 announced nuclear test', Press release, 25 May 2009, <http://www.ctbto.org/press-centre/press-releases/2009/ctbtos-initial-findings-on-the-dprks-2009-announced-nuclear-test/>; *BJI data*: International Seismological Centre (ISC), 'Event 13193113 North Korea', ISC On-line Bulletin, <http://www.isc.ac.uk/cgi-bin/web-db-v3?event_id=13193113>; *CEME data*: CEME, 'Information message on underground nuclear explosion conducted in North Korea on May 25, 2009', 26 May 2009, <http://www.ceme.gsras.ru/cgi-bin/info_quakee.pl?mode=1&id=125>; *NEIC data*: NEIC, 'Magnitude 4.7: North Korea', Preliminary Earthquake Report, 7 Aug. 2009, <http://earthquake.usgs.gov/eqcenter/recenteqsww/Quakes/us2009hbaf.php>; *NORSAR data*: NORSAR, 'Announced nuclear test by North Korea', Press release, <http://www.norsar.no/pc-61-99-Announced-Nuclear-Test-by-North-Korea.aspx>.

radionuclide monitoring and satellite imagery analysis.[7] Following the event, a combination of these technologies was employed by the IMS, individual states and many research institutions to verify whether there had indeed been an explosion and, if so, its characteristics such as location, yield and nature.

[7] US National Academy of Sciences, *Technical Issues Related to the Comprehensive Nuclear Test Ban Treaty* (National Academy Press: Washington, DC, 2002), pp. 39–41.

Seismic data recorded at monitoring stations around the world was used to estimate the time, location and size of the event (see table 8B.1). The recorded seismic wave patterns, the depth of the event (less than 1 km) and the fact that it occurred so close to the site of the 2006 nuclear test indicate that the 2009 event was an explosion rather than an earthquake.[8]

Based on the seismic data, most estimates of the yield of the explosion vary between 2 and 7 kilotons, which is 'about 5 times stronger' than the 2006 test.[9] In June 2009 the US Government estimated the yield as 'approximately a few kilotons', and non-governmental scientists tend to agree with this assessment.[10]

Seismic data alone is insufficient to confirm that an underground explosion is nuclear. Following North Korea's 2006 test, air sampling detected traces of radioxenon, which confirmed the nuclear nature of the explosion.[11] After the 2009 event no trace of radioxenon or other debris was reported to have been found.[12] Despite this, there is consensus among scientists and CTBTO officials that the explosion on 25 May 2009 in North Korea was most probably nuclear.[13] In order to establish the nuclear nature of the event with absolute certainty, on-site inspection is needed.[14]

Due to the absence of detected radioactive effluents from the explosion, it is not possible to establish whether the North Korean test in 2009 used uranium or plutonium. It is widely assumed that it used plutonium.[15] The extent to which the North Korean nuclear test was successful is also uncertain because, unlike in 2006, North Korea did not preannounce the expected yield of the explosion. Some experts have questioned the success of the test, because the several-kiloton yield of the North Korean device is still a few times smaller than the yield that the initial nuclear tests by nuclear weapon states have historically produced.[16]

[8] Pearce, R. G. et al., 'The announced nuclear test in the DPRK on 25 May 2009', *CTBTO Spectrum*, no. 13 (Sep. 2009), p. 27.

[9] MacKenzie, D., 'North Korea's nuke test could have positive outcome', *New Scientist*, 26 May 2009. The nuclear test explosion in 2006 was estimated to have had a yield under 1 kt. Fedchenko, V. and Ferm Hellgren, R., 'Nuclear explosions, 1945–2006', *SIPRI Yearbook 2007*, p. 553.

[10] US Office of the Director of National Intelligence, 'Statement by the Office of the Director of National Intelligence on North Korea's declared nuclear test on May 25, 2009', News Release no. 23-09, 15 June 2009, <http://www.dni.gov/press_releases/20090615_release.pdf>; and Kalinowski, M. B., 'Second nuclear test conducted by North Korea on 25 May 2009', Fact sheet, University of Hamburg, Carl Friedrich von Weizsäcker Centre for Science and Peace Research (ZNF), 27 May 2009, <http://www.znf.uni-hamburg.de/Factsheet_NK.pdf>.

[11] Fedchenko and Ferm Hellgren (note 9), p. 553; and Williams, D. L., 'Characterizing nuclear weapons explosions based upon collected radio-nuclide effluents', Memorandum, Massachusetts Institute of Technology, Department of Nuclear Science and Engineering, 21 Oct. 2006, <http://web.mit.edu/tyler9/www/Characterizing Nuclear Weapons Explosions.doc>.

[12] Pearce et al. (note 8), pp. 28–29.

[13] CTBTO, 'Experts sure about nature of the DPRK event', Press release, 12 June 2009, <http://www.ctbto.org/press-centre/highlights/2009/experts-sure-about-nature-of-the-dprk-event/>; and Clery, D., 'Verification experts puzzled over North Korea's nuclear test', *Science*, 19 June 2009.

[14] CTBTO, 'Homing in on the event', Press release, 29 May 2009, <http://www.ctbto.org/press-centre/highlights/2009/homing-in-on-the-event/>.

[15] See chapter 9, section IV, in this volume.

[16] Park, J., 'The North Korean nuclear test: what the seismic data says', *Bulletin of the Atomic Scientists*, 26 May 2009.

III. Estimated number of nuclear explosions, 1945–2009

Table 8B.2 lists the known nuclear explosions to date, including nuclear tests conducted in nuclear weapon test programmes, explosions carried out for peaceful purposes and the two nuclear bombs dropped on Hiroshima and Nagasaki in August 1945. The totals also include tests for safety purposes carried out by France, the Soviet Union and the USA, irrespective of the yield and of whether they caused a nuclear explosion.[17] The table does not include subcritical experiments. Simultaneous detonations, also called salvo explosions, were carried out by the USA (from 1963) and the Soviet Union (from 1965), mainly for economic reasons.[18] Of the Soviet tests, 20 per cent were salvo experiments, as were 6 per cent of the US tests.

'Underground nuclear test' is defined by the 1990 Protocol to the 1974 Soviet–US Threshold Test-Ban Treaty (TTBT) as 'either a single underground nuclear explosion conducted at a test site, or two or more underground nuclear explosions conducted at a test site within an area delineated by a circle having a diameter of two kilometers and conducted within a total period of time of 0.1 second'.[19] 'Underground nuclear explosion' is defined by the 1976 Soviet–US Peaceful Nuclear Explosions Treaty (PNET) as 'any individual or group underground nuclear explosion for peaceful purposes'.[20] 'Group explosion' is defined as 'two or more individual explosions for which the time interval between successive individual explosions does not exceed five seconds and for which the emplacement points of all explosives can be inter-connected by straight line segments, each of which joins two emplacement points and each of which does not exceed 40 kilometers'.[21]

A number of moratoriums, both voluntary and legal, have been observed. The USSR, the UK and the USA observed a moratorium on testing from November 1958 to September 1961. The 1963 Partial Test-Ban Treaty (PTBT), which prohibits nuclear explosions in the atmosphere, in outer space and under water, entered into force on 10 October 1963.[22] The USSR observed a unilateral moratorium on testing between August 1985 and February 1987. The USSR and then Russia observed a moratorium on testing from January 1991 and the USA from October 1992, until they signed the Comprehensive Nuclear-Test-Ban Treaty (CTBT) on 24 September 1996; France observed a similar moratorium from April 1992 to September 1995. The CTBT, which has not yet entered into force, would prohibit the carrying out of any nuclear explosion.[23]

[17] In a safety experiment, or a safety trial, more or less fully developed nuclear devices are subjected to simulated accident conditions. The nuclear weapon core is destroyed by conventional explosives with no or very small releases of fission energy. The United Kingdom also carried out numerous safety tests, but they are not included in table 2 because of their high number.

[18] The USSR conducted simultaneous tests including as many as 8 devices on 23 Aug. 1975 and on 24 Oct. 1990 (the last Soviet test).

[19] 1999 TTBT Protocol, Section I, para. 2. For a summary and other details of the 1974 Treaty on the Limitation of Under-ground Nuclear Weapon Tests and its Protocol see annex A in this volume.

[20] PNET, Article II.a. For a summary and other details of the 1976 Treaty on Underground Nuclear Explosions for Peaceful Purposes see annex A in this volume.

[21] PNET (note 20), Article II.c.

[22] The parties include India, Pakistan, Russia, the UK and the USA. For a full list see annex A.

[23] The signatories include China, France, Russia, the UK and the USA. For a full list see annex A.

Table 8B.2. Estimated number of nuclear explosions, 1945–2009

a = atmospheric (or in a few cases underwater); u = underground.

	USA[a]		Russia/ USSR		UK[a]		France		China		India		Pakistan		North Korea		
Year	a	u	a	u	a	u	a	u	a	u	a	u	a	u	a	u	Total
1945	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3
1946	2[b]	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
1947	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1948	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3
1949	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	1
1950	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1951	15	1	2	–	–	–	–	–	–	–	–	–	–	–	–	–	18
1952	10	–	–	–	1	–	–	–	–	–	–	–	–	–	–	–	11
1953	11	–	5	–	2	–	–	–	–	–	–	–	–	–	–	–	18
1954	6	–	10	–	–	–	–	–	–	–	–	–	–	–	–	–	16
1955	17[b]	1	6[b]	–	–	–	–	–	–	–	–	–	–	–	–	–	24
1956	18	–	9	–	6	–	–	–	–	–	–	–	–	–	–	–	33
1957	27	5	16[b]	–	7	–	–	–	–	–	–	–	–	–	–	–	55
1958	62[c]	15	34	–	5	–	–	–	–	–	–	–	–	–	–	–	116
1959	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1960	–	–	–	–	–	–	3	–	–	–	–	–	–	–	–	–	3
1961	–	10	58[b]	1	–	–	1	1	–	–	–	–	–	–	–	–	71
1962	39[b]	57	78	1	–	2	–	1	–	–	–	–	–	–	–	–	178
1963	4	43	–	–	–	–	–	3	–	–	–	–	–	–	–	–	50
1964	–	45	–	9	–	2	–	3	1	–	–	–	–	–	–	–	60
1965	–	38	–	14	–	1	–	4	1	–	–	–	–	–	–	–	58
1966	–	48	–	18	–	–	6	1	3	–	–	–	–	–	–	–	76
1967	–	42	–	17	–	–	3	–	2	–	–	–	–	–	–	–	64
1968	–	56	–	17	–	–	5	–	1	–	–	–	–	–	–	–	79
1969	–	46	–	19	–	–	–	–	1	1	–	–	–	–	–	–	67
1970	–	39	–	16	–	–	8	–	1	–	–	–	–	–	–	–	64
1971	–	24	–	23	–	–	5	–	1	–	–	–	–	–	–	–	53
1972	–	27	–	24	–	–	4	–	2	–	–	–	–	–	–	–	57
1973	–	24	–	17	–	–	6	–	1	–	–	–	–	–	–	–	48
1974	–	22	–	21	–	1	9	–	1	–	–	1	–	–	–	–	55
1975	–	22	–	19	–	–	–	2	–	1	–	–	–	–	–	–	44
1976	–	20	–	21	–	1	–	5	3	1	–	–	–	–	–	–	51
1977	–	20	–	24	–	–	–	9	1	–	–	–	–	–	–	–	54
1978	–	19	–	31	–	2	–	11	2	1	–	–	–	–	–	–	66
1979	–	15	–	31	–	1	–	10	1	–	–	–	–	–	–	–	58
1980	–	14	–	24	–	3	–	12	1	–	–	–	–	–	–	–	54
1981	–	16	–	21	–	1	–	12	–	–	–	–	–	–	–	–	50
1982	–	18	–	19	–	1	–	10	–	1	–	–	–	–	–	–	49
1983	–	18	–	25	–	1	–	9	–	2	–	–	–	–	–	–	55
1984	–	18	–	27	–	2	–	8	–	2	–	–	–	–	–	–	57
1985	–	17	–	10	–	1	–	8	–	–	–	–	–	–	–	–	36
1986	–	14	–	–	–	1	–	8	–	–	–	–	–	–	–	–	23
1987	–	14	–	23	–	1	–	8	–	1	–	–	–	–	–	–	47
1988	–	15	–	16	–	–	–	8	–	1	–	–	–	–	–	–	40
1989	–	11	–	7	–	1	–	9	–	–	–	–	–	–	–	–	28

	USA[a]		Russia/ USSR		UK[a]		France		China		India		Pakistan		North Korea		
Year	a	u	a	u	a	u	a	u	a	u	a	u	a	u	a	u	Total
1990	–	8	–	1	–	1	–	6	–	2	–	–	–	–	–	–	18
1991	–	7	–	–	–	1	–	6	–	–	–	–	–	–	–	–	14
1992	–	6	–	–	–	–	–	–	–	2	–	–	–	–	–	–	8
1993	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	1
1994	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	2
1995	–	–	–	–	–	–	–	5	–	2	–	–	–	–	–	–	7
1996	–	–	–	–	–	–	–	1	–	2	–	–	–	–	–	–	3
1997	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1998	–	–	–	–	–	–	–	–	–	–	–	2[d]	–	2[d]	–	–	4
1999	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2000	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2001	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2002	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2003	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2004	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2005	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2006	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1
2007	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2008	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
2009	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1
Subtotal	**217**	**815**	**219**	**496**	**21**	**24**	**50**	**160**	**23**	**22**	**–**	**3**	**–**	**2**	**–**	**2**	
Total	**1 032**		**715**		**45**		**210**		**45**		**3**		**2**		**2**		**2 054**

Notes: This table is based on tables published in previous editions of the SIPRI Yearbook, most recently Fedchenko, V. and Ferm Hellgren, R., 'Nuclear explosions, 1945–2006', *SIPRI Yearbook 2007*, table 12B.2.

[a] All British tests from 1962 were conducted jointly with the USA at the US Nevada Test Site but are listed only under 'UK' in this table. Thus, the number of US tests is higher than shown. Safety tests carried out by the UK are not included in the table.

[b] 1 of these tests was carried out under water.

[c] 2 of these tests were carried out under water.

[d] India's detonations on 11 and 13 May 1998 are listed as 1 test for each date. The 5 detonations by Pakistan on 28 May 1998 are also listed as 1 test.

Sources: Swedish Defence Research Agency (FOI), various estimates, including information from the CTBTO International Data Centre and information from the Swedish National Data Centre provided to the author in Feb. 2007 and Oct. 2009; Reports from the Australian Seismological Centre, Australian Geological Survey Organisation, Canberra; US Department of Energy (DOE), *United States Nuclear Tests: July 1945 through September 1992* (DOE: Washington, DC, 1994); Norris, R. S., Burrows, A. S. and Fieldhouse, R. W., Natural Resources Defense Council, *Nuclear Weapons Databook*, vol. 5, *British, French and Chinese Nuclear Weapons* (Westview: Boulder, CO, 1994); Direction des centres d'experimentations nucléaires (DIRCEN) and Commissariat à l'Énergie Atomique (CEA), *Assessment of French Nuclear Testing* (DIRCEN and CEA: Paris, 1998); Russian ministries of Atomic Energy and Defence, *USSR Nuclear Weapons Tests and Peaceful Nuclear Explosions, 1949 through 1990* (Russian Federal Nuclear Center (VNIIEF): Sarov, 1996); and Natural Resources Defense Council, 'Archive of nuclear data', <http://www.nrdc.org/nuclear/nudb/datainx.asp>.