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Nuclear explosions, 1945–2013

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Contents

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XI. Nuclear explosions, 1945–2013

VITALY FEDCHENKO

In February 2013 the Democratic People's Republic of Korea (DPRK, or North Korea) conducted its third nuclear test explosion, following tests conducted in October 2006 and April 2009.[1] This event brought the total number of nuclear explosions recorded since 1945 to 2055.

The nuclear test in North Korea

On 24 January 2013 North Korea's official news agency, the Korean Central News Agency (KCNA), issued a statement announcing that the country would conduct 'a nuclear test of higher level' as a response to the United Nations Security Council's condemnation of a North Korean rocket launch, in breach of UN sanctions.[2] An explosion took place at 02:57 UTC on 12 February (11:57 local time). A few hours later the KCNA announced that the event was North Korea's third successful underground nuclear test that was 'conducted in a safe and perfect way on a high level with the use of a smaller and light A-bomb unlike the previous ones, yet with great explosive power'.[3] The announcement added that 'the test did not give any adverse effect to the surrounding ecological environment'.

The North Korean claims had to be verified by available technologies. The technologies used for verification of underground nuclear tests include seismology, radionuclide monitoring and satellite imagery analysis.[4] Following the event, a combination of these technologies was employed by international organizations, 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.

The 1996 Comprehensive Nuclear-Test-Ban Treaty (CTBT) is a multilateral treaty that will prohibit the carrying out of any nuclear explosion.[5] The Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) has been established to prepare for the entry

[1] On the earlier tests see Fedchenko, V. and Ferm Hellgren, R., 'Nuclear explosions, 1945–2006', *SIPRI Yearbook 2007*; and Fedchenko, V., 'Nuclear explosions, 1945–2009', *SIPRI Yearbook 2010*.

[2] Korean Central News Agency (KCNA), 'DPRK NDC vows to launch all-out action to defend sovereignty of country', 24 Jan. 2013. The KCNA's statements are available on the website of the Korean News Service in Tokyo, <http://www.kcna.co.jp/>. For further political background to the explosion see chapter 7, section II, in this volume.

[3] Korean Central News Agency (KCNA), 'KCNA report on successful 3rd underground nuclear test', 12 Feb. 2013.

[4] US National Academy of Sciences, *Technical Issues Related to the Comprehensive Nuclear Test Ban Treaty* (National Academy Press: Washington, DC, 2002), pp. 39–41; and Dahlman, O. et al., *Detect and Deter: Can Countries Verify the Nuclear Test Ban?* (Springer: Dordrecht, 2011), pp. 29–76.

[5] For a summary and other details of the CTBT see annex A, section I, in this volume.

into force of the CTBT, including through the establishment of an International Monitoring System (IMS) to detect nuclear explosions. While the CTBT had been ratified by 159 states at the time of the explosion, it cannot enter into force until it has been signed and ratified by 44 states with certain nuclear facilities. North Korea, which is one of these 44 states, has not signed the treaty and therefore does not participate in the IMS.

Seismic data recorded at monitoring stations around the world was used to estimate the time, location and size of the event (see table 6.15). The IMS issued its first report to CTBTO member states less than two hours after the explosion.[6] The recorded seismic wave patterns, the depth of the event (less than 1 kilometre) and the fact that it occurred so close to the site of both the 2006 and 2009 nuclear tests indicated that the 2013 event was an explosion rather than an earthquake.[7]

Based on seismic data, satellite imagery and information from the previous two tests, most estimates of the yield of the explosion vary between about 5 and 16 kilotons, which is 'about 2.5 to 3 times larger in yield' than the 2009 test (and therefore 12.5 to 15 times larger than the 2006 test).[8]

Seismic data alone is insufficient to confirm that an underground explosion is nuclear. Following North Korea's 2006 test, the nuclear nature of the explosion was confirmed when air sampling detected traces of radioxenon (i.e. radioactive isotopes of xenon, which are released from a nuclear explosion).[9] After the 2009 event no trace of radioxenon or other radioactive debris was reported to have been found.[10]

On 23 April 2013 the CTBTO announced that two of its stations, in Takasaki, Japan, and Ussuriisk, Russia, had earlier in the month detected two radioactive isotopes of xenon—xenon-131m and xenon-133—which act as a 'chronometer', determining the time of the event in which these isotopes were created.[11] The ratio of concentrations of these isotopes in air samples was consistent with a nuclear fission event that would have taken place more than 50 days before detection. (The xenon detection in Japan occurred 55 days after the explosion.) Atmospheric transfer modelling, conducted by the CTBTO, identified the site of the previous two nuclear

[6] CTBTO, 'On the CTBTO's detection in North Korea', Press release, 12 Feb. 2013, <http://www.ctbto.org/press-centre/press-releases/2013/on-the-ctbtos-detection-in-north-korea/>.

[7] Richards, P., 'Seismic detective work: CTBTO monitoring system "very effective" in detecting North Korea's third nuclear test', *CTBTO Spectrum*, no. 20 (July 2013), p. 22.

[8] Richards (note 7); and Zhang, M. and Wen, L., 'High-precision location and yield of North Korea's 2013 nuclear test', *Geophysical Research Letters*, vol. 40, no. 12 (28 June 2013). The nuclear test explosion in 2006 was estimated to have had a yield under 1 kt and that in 2009 a yield of 2–7 kt. Fedchenko and Ferm Hellgren (note 1), p. 553; and Fedchenko (note 1), p. 373.

[9] Fedchenko and Ferm Hellgren (note 1), p. 553.

[10] Pearce, R. G. et al., 'The announced nuclear test in the DPRK on 25 May 2009', *CTBTO Spectrum*, no. 13 (Sep. 2009), pp. 28–29.

[11] CTBTO, 'CTBTO detects radioactivity consistent with 12 February announced North Korean nuclear test', Press release, 23 Apr. 2013, <http://www.ctbto.org/press-centre/press-releases/2013/ctbto-detects-radioactivity-consistent-with-12-february-announced-north-korean-nuclear-test/>.

Table 6.15. Data on North Korea’s nuclear explosion, 12 February 2013

Source[a]	Origin time (UTC)	Latitude	Longitude	Error margin[b]	Body wave magnitude[c]
IDC[d]	02:57:51	41.3005° N	129.0652° E	±8.1 km[e]	4.9
CEME (Russia)	02:57:49.4	41.31° N	129.1° E	. .	5.3
IGGCAS (China)	02:57:51.3	41.2927° N	129.0730° E	. .	4.93±0.21
NEIC (United States)	02:57:51	41.308° N	129.076° E	±11.2 km[f]	5.1
NORSAR (Norway)	02:57:51	41.28° N	129.07° E	. .	5.0

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; CEME = Russian Academy of Sciences, Geophysical Survey, Central Experimental Methodical Expedition, Obninsk, Kaluga oblast; IGGCAS = Chinese Academy of Sciences, Institute of Geology and Geophysics, Beijing; NEIC = US Geological Survey, National Earthquake Information Center, Denver, CO; and NORSAR = Norwegian Seismic Array, 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 *c.* 85% 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*: CTBTO, ‘Update on CTBTO findings related to the announced nuclear test by North Korea’, Press release, 15 Feb. 2013, <http://www.ctbto.org/press-centre/highlights/2013/update-on-ctbto-findings-related-to-the-announced-nuclear-test-by-north-korea/>, and NORSAR, ‘Detection and location of the February 12, 2013, announced nuclear test in North Korea’, *NORSAR Scientific Report*, no. 2-2012 (June 2013), p. 26; *CEME*: CEME, ‘Information message about underground nuclear explosion made in North Korea on February 12, 2013’, [n.d.], <http://www.ceme.gsras.ru/cgi-bin/info_quakee.pl?mode=1&id=204>; *IGGCAS*: Feng, X. et al., [Preliminary findings on 12 February 2013 Korean underground nuclear test], IGGCAS, 13 Feb. 2013, <http://www.igg.cas.cn/xwzx/zhxw/201302/t20130213_3763392.html> (in Chinese); and Feng, X. et al., [Precision positioning of 12 February 2013 North Korean underground nuclear test], IGGCAS, 28 Feb. 2013, <http://www.igg.cas.cn/xwzx/zhxw/201302/t20130228_3783953.html> (in Chinese); *NEIC*: NEIC, ‘M5.1—24km ENE of Sungjibaegam, North Korea (BETA)’, US Geological Survey, 7 Aug. 2009, <http://comcat.cr.usgs.gov/earthquakes/eventpage/usc000f5t0#scientific_summary>; *NORSAR*: NORSAR, ‘Nuclear explosion in North Korea, February 12, 2013: observations, magnitudes and location estimates’, Press release, <http://www.norsar.no/norsar/about-us/News/2013/NuclearExplosionDPRK12Feb2013>.

tests as a possible source of the xenon emission. Since the radioxenon was detected so late after the event, it was not possible to determine if it had been produced by fission of uranium or plutonium.[12] This, in turn, meant that it was not possible to assess whether North Korea may have used highly enriched uranium in the explosive device (see section IX above).

Estimated number of nuclear explosions, 1945–2013

Since 1945 there have been 2055 known nuclear explosions, carried out by eight states—the United States, the Soviet Union, the United Kingdom, France, China, India, Pakistan and North Korea (see table 6.16). This total includes 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 total also includes 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.[13] It does not include subcritical experiments (i.e. those that did not sustain a nuclear chain reaction). Simultaneous detonations, also called salvo explosions, were carried out by the USA (from 1963) and the Soviet Union (from 1965), mainly for economic reasons.[14] Of the Soviet tests, 20 per cent were salvo experiments, as were 6 per cent of the US tests.

A number of moratoriums, both voluntary and legal, have been observed. The Soviet Union, 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.[15] The Soviet Union observed a unilateral moratorium on testing between August 1985 and February 1987. The Soviet Union and then Russia observed a moratorium on testing from January 1991 and the USA from October 1992, until they signed the 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.[16]

[12] 'Detection of radioactive gases consistent with North Korean test underlines strength of CTBTO monitoring system', *CTBTO Spectrum*, no. 20 (July 2013), p. 26.

[13] 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 UK also carried out numerous safety tests, but they are not included in table 5.16 because of their high number.

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

[15] The parties include India, Pakistan, Russia, the UK and the USA. For a full list see annex A, section I, in this volume.

[16] The signatories include China, France, Russia, the UK and the USA. For a full list see annex A, section I, in this volume.

Table 6.16. Estimated number of nuclear explosions, 1945–2013

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

	USA[b]		Russia/ USSR		UK[b]		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[c]	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	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[c]	1	6[c]	–	–	–	–	–	–	–	–	–	–	–	–	–	24
1956	18	–	9	–	6	–	–	–	–	–	–	–	–	–	–	–	33
1957	27	5	16[c]	–	7	–	–	–	–	–	–	–	–	–	–	–	55
1958	62[d]	15	34	–	5	–	–	–	–	–	–	–	–	–	–	–	116
1959	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1960	–	–	–	–	–	–	3	–	–	–	–	–	–	–	–	–	3
1961	–	10	58[c]	1	–	–	1	1	–	–	–	–	–	–	–	–	71
1962	39[c]	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[b]		Russia/ USSR		UK[b]		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[e]	–	2[e]	–	–	4
2006	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1
2009	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1
2013	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1
Subtotal	**217**	**815**	**219**	**496**	**21**	**24**	**50**	**160**	**23**	**22**	–	**3**	–	**2**	–	**3**	
Total	**1 032**		**715**		**45**		**210**		**45**		**3**		**2**		**3**		**2 055**

[a] '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' (Section I, para. 2). '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' (Article II(a)). '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' (Article II(c)).

[b] 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.

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

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

[e] 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: Bergkvist, N.-O. and Ferm, R., *Nuclear Explosions 1945–1998* (Swedish Defence Research Establishment/SIPRI: Stockholm, July 2000); Swedish Defence Research Agency (FOI), various estimates, including information from the CTBTO International Data Centre and 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>.