XI. Nuclear explosions, 1945–2017

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On 3 September 2017 the Democratic People's Republic of Korea (DPRK, or North Korea) conducted its sixth nuclear test explosion, following tests conducted in January and September 2016, February 2013, May 2009 and October 2006.[1] This 2017 test brought the total number of nuclear explosions recorded since 1945 to 2058.

The September 2017 nuclear test

On 3 September 2017 at 03:30 Coordinated Universal Time (12:00 local time) North Korea conducted an underground test explosion at the Punggye-ri Nuclear Test Facility under Mount Mantap in the north-east of the country.[2] Shortly after, the Korean Central News Agency (KCNA) announced that the event was a successful test of a hydrogen bomb for an intercontinental ballistic missile (ICBM) and published a statement by the Nuclear Weapons Institute (NWI) of North Korea detailing the features of the test device.[3]

The publication after a test of discussion by the NWI of the test device's features is a new development: it occurred for the first time after the fifth test in September 2016. The NWI noted that the test carried out in September 2017 was of a bomb of 'unprecedentedly big power' and proclaimed the test a success. The NWI also stated that North Korea had conducted 'experimental measurements' to verify the performance of a new 'H-bomb' design, in terms of (*a*) its 'total explosion power' (yield); (*b*) its 'fission to fusion power' ratio; (*c*) the 'precision of the compression technology and the fission chain reaction start control technology of the first system of the H-bomb', meaning the performance of the high explosive implosion assembly and the neutron initiator in the primary; and (*d*) the 'nuclear material utility rate in the first system and the second system', or the proportion of the fissile material in the primary that underwent fission, as opposed to being scattered by the explosion, and the amount of material that underwent either fusion or fission in the secondary.[4] Some descriptions of the test device's features,

[1] On the earlier tests see Fedchenko, V. and Ferm Hellgren, R., 'Nuclear explosions, 1945–2006', *SIPRI Yearbook 2007*; Fedchenko, V., 'Nuclear explosions, 1945–2009', *SIPRI Yearbook 2010*; Fedchenko, V., 'Nuclear explosions, 1945–2013', *SIPRI Yearbook 2014*; and Fedchenko, V., 'Nuclear explosions, 1945–2016', *SIPRI Yearbook 2017*.

[2] Lee, M. Y. H., 'North Korea's latest nuclear test was so powerful it reshaped the mountain above it', *Washington Post*, 14 Sep. 2017.

[3] Korean Central News Agency, 'DPRK Nuclear Weapons Institute on successful test of H-bomb for ICBM', 3 Sep. 2017.

[4] The ratio of fission to fusion energy (i.e. the share of energy from fission and fusion reactions in the total yield) determines the amount of long-term contamination by radioactive isotopes. Less fission means less long-lived radioactive isotopes in the fallout, so the weapon can be treated

Table 6.15. Data on North Korea's nuclear explosion, 3 September 2017

Source[a]	Origin time (UTC)	Latitude	Longitude	Error margin[b]	Body-wave magnitude[c]
IDC[d]	03:30:06.09 ± 3.7	41.3256° N	129.0760° E	±6.7 km[e]	6.07 ± 0.1
CEME	03:29:59.0	41.3° N	129.1° E	. .	6.3
NEIC	03:30:01.760	41.332° N	129.030° E	±1.4 km[f]	6.3
IES CAS	03:30:00	41.3° N	129.1° E	. .	6.3
KMA	03:29:58	41.302° N	129.080° E	. .	5.7
FOI	03:30	41.3° N	129.1° E	. .	6.1

. . = data not available; CEME = Russian Academy of Sciences, Geophysical Survey, Central Experimental Methodical Expedition, Obninsk, Kaluga oblast, Russia; FOI = Swedish Defence Research Agency, Stockholm, Sweden; IDC = Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), International Data Centre, Vienna, Austria; IES CAS = Institutions of Earth Science, Chinese Academy of Science, Beijing, China; km = kilometres; KMA = Korean Meteorological Administration, Seoul, South Korea; NEIC = US Geological Survey, National Earthquake Information Center, Denver, CO, United States; UTC = Coordinated Universal Time.

[a] Because of differences between estimates regarding the precise location and magnitude of the explosion, data from 6 sources—1 internationally recognized body and 5 national bodies—is provided for comparison.

[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 an unambiguous way of indicating the size of an explosion.

[d] The IDC was 'in a test and provisional operation mode only' so 41 of the 50 primary and 96 of the 120 auxiliary seismic 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. The confidence ellipse area was 109 square km, or almost 10 times smaller than the maximum area allowed to be inspected under the Comprehensive Nuclear-Test-Ban Treaty On-Site Inspection regime (1000 square km).

[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: CTBTO, IDC, 'Technical briefing', 3 Sep. 2017; and CTBTO, IDC, 'Technical findings', 7 Sep. 2017; CEME, [Information message about underground nuclear explosion made in North Korea on 3 September 2017], 4 Sep. 2017 (in Russian); NEIC, 'M 6.3 nuclear explosion: 21 km ENE of Sungjibaegam, North Korea', US Geological Survey, [n.d.]; IES CAS, 'Research letters: September 3, 2017, preliminary results of seismological discrimination, depth and equivalence estimates for North Korea's nuclear tests', 4 Sep. 2017; KMA, Earthquake Volcano Monitoring Division, 'Artificial earthquake occurred in North Hamkyung Province', Press release, 3 Sep. 2017; and FOI, 'Nuclear weapons test in North Korea', Press release, 11 Sep. 2017.

such as 'the directional combination structure and multi-layer radiation explosion-proof structural design of the first system and the second system' and the 'light thermal radiation-resisting materials and neutron-resisting

as 'cleaner' by military planners. This could be important for those considering the tactical use of nuclear weapons.

materials', are harder to interpret specifically on the basis of open-source descriptions of thermonuclear weapon designs. However, these statements seem to be consistent with the 'Teller–Ulam' thermonuclear design, which is ostensibly used by all states with thermonuclear weapons.[5]

As was the case with the fifth test, the NWI statement noted that 'there were neither emission through ground surface nor leakage of radioactive materials nor did it have any adverse impact on the surrounding ecological environment'.

Verification of the September 2017 North Korean test by the international community

The international community—international organizations, individual states and many research institutions—sought to verify North Korea's claims concerning the test using a combination of available technologies, including seismology, radionuclide monitoring and satellite imagery analysis.[6]

The 1996 Comprehensive Nuclear-Test-Ban Treaty (CTBT) is a multilateral treaty that, once it enters into force, will prohibit the carrying out of any nuclear explosion.[7] The Preparatory Commission for the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) has been established to prepare for the entry into force of the CTBT. These preparations include the creation of an International Monitoring System (IMS) to detect nuclear explosions. While the CTBT had been ratified by 166 states as of 1 February 2018, it cannot enter into force until it has been signed and ratified by 44 states that possess 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 3 September 2017 explosion (see table 6.15). The seismic wave patterns recorded, the depth of the event (less than 1 kilometre) and the fact that it occurred so close to the five previous nuclear tests (a characteristic distance being a few hundred metres) all indicate that it was an explosion rather than an earthquake.[8] The characteristic feature of this test was that its yield (see below) was large enough to produce aftershocks that themselves were large enough to be detected by seismic

[5] Korean Central News Agency (note 3).

[6] 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.

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

[8] Comprehensive Nuclear-Test-Ban Treaty Organization, International Data Centre, 'Technical findings', 7 Sep. 2017.

monitoring stations.[9] In addition, synthetic aperture radar (SAR) satellite imagery was used to show that the peak of Mount Mantap had 'incurred a visible amount of subsidence', and an area of about 35 hectares 'of the south-west flank of the mountain was displaced by several meters'.[10] The seismic events that followed the test explosion have reportedly led the governments of the United States and China to conclude that a collapse of an explosion cavity or tunnels had taken place.[11]

Even though there can be little doubt in cases of an explosion of this size, strictly speaking, seismic data alone is insufficient to confirm that an underground explosion is a nuclear explosion. Following North Korea's 2006 and 2013 tests, the nuclear nature of the explosion was confirmed when air sampling detected traces of radioxenon—radioactive isotopes of xenon that are released from a nuclear explosion.[12] No trace of radioxenon or other radioactive debris was reported found after the 2009 event, or after either of the events in 2016. Radioxenon detection after the 2017 test produced ambiguous results. The Government of the Republic of Korea (South Korea) announced that its Nuclear Safety and Security Commission found xenon-133 in 'ground, air and maritime' samples collected locally after the test.[13] The CTBTO also detected and investigated elevated concentrations of radioxenon, but found these 'not conclusive with regard to a possible association to the seismic event on 3 September'. It therefore determined that 'no CTBT-relevant radionuclides were detected by the IMS that could be unambiguously linked to a nuclear test in DPRK in September 2017'.[14]

Discussion of the September 2017 test results

North Korea does not announce the planned or measured yields from its test explosions. Estimates made by international researchers vary significantly. The published body-wave magnitude measurements—an unambiguous way of registering the size of a seismic event—ranged from 5.7 to 6.3.[15] As a result of this discrepancy and differences in the empirical methods used to convert

[9] Kitov, I. O. and Rozhkov, M. V., 'Discrimination of the DPRK underground explosions and their aftershocks using the P/S spectral amplitude ratio', Cornell University Library, Preprint, 5 Dec. 2017.

[10] Lee (note 2).

[11] Dill, C., 'North Korea nuclear test: "tunnel collapse" may provide clues', BBC News, 3 Sep. 2017.

[12] Fedchenko and Ferm Hellgren (note 1), p. 553; and Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO), 'CTBTO detects radioactivity consistent with 12 February announced North Korean nuclear test', Press release, 23 Apr. 2013.

[13] Yonhap News Agency, 'Traces of xenon detected in S. Korea following N. Korea's nuke test', 8 Sep. 2017.

[14] American Geophysical Union (AGU), Proceedings of the AGU Fall Meeting 2017, New Orleans, 11–15 Dec. 2017. For a detailed discussion of CTBT-relevant radionuclides and the CTBTO procedures for their detection and analysis see De Geer, L. E., 'Radionuclide signatures for post-explosion environments', ed. V. Fedchenko, SIPRI, *The New Nuclear Forensics: Analysis of Nuclear Materials for Security Purposes* (Oxford University Press: Oxford, 2015), pp. 128–55.

[15] For further detail on body-wave magnitude see the United States Geological Survey website.

these values into explosive yields, yield estimates ranged from 50 kilotons to 1 megaton.[16] Most researchers agree, however, that the September 2017 test was about an order of magnitude larger than the previous one in September 2016. For example, the US Government's assessment of the explosive yield is 140 kt, the Norwegian Government's figure is 120 kt and the Swedish Government and Chinese university researchers, working independently, estimate a yield in the range of 100–200 kt.[17]

Most commentators found North Korea's claim that the nuclear explosive device tested on 3 September 2017 was a thermonuclear weapon to be plausible.[18] It should be noted, however, that these findings, which may indeed be correct, are based on indirect evidence. The only direct evidence associated with the event that is described in open sources is seismic wave data. Seismic waves can provide evidence of the size of the explosion but do not give information on the nuclear, boosted or thermonuclear nature of the explosive device, or on whether the test device used uranium or plutonium. The radioactive debris—and specifically the radioactive micro-particles—associated with the explosion must be analysed to discern that kind of detail.[19]

The explosive yield of the tested device is consistent with all three of the above-mentioned types of weapon (nuclear, boosted or thermonuclear) and therefore cannot be used to discriminate between them. For example, the B61 nuclear bomb—a true thermonuclear two-stage gravity bomb currently deployed in the US arsenal—reportedly has variants with yields of between a few kilotons and 300 kt.[20] By contrast, the largest publicly known pure-fission nuclear explosive device ever tested by the USA, the Ivy King test explosion on 16 November 1952, had a yield of about 500 kt.[21] Moreover, some commentators point out that it is technically easier to achieve a 100-kt yield in an underground test with no constraints on size and weight than to design a miniature warhead with a yield of 10–20 kt.[22]

[16] See table 6.15; and Incorporated Research Institutions of Seismology, 'Special event: 2017 North Korean nuclear test', 23 Jan. 2018.

[17] Panda, A., 'US intelligence: North Korea's sixth test was a 140 kiloton "advanced nuclear" device', The Diplomat, 6 Sep. 2017; NORSAR, 'Large nuclear test in North Korea on 3 September 2017', 3 Sep. 2017; University of Science and Technology of China (USTC), 'North Korea's 3 September 2017 nuclear test location and yield: seismic results from USTC', [n.d.]; and Swedish Defence Research Agency (FOI), 'Nuclear weapons test in North Korea', Press release, 11 Sep. 2017.

[18] See e.g. Lewis, J., 'Welcome to the thermonuclear club, North Korea!', *Foreign Policy*, 4 Sep. 2017.

[19] De Geer (note 14), pp. 128–55.

[20] Hansen, C., *Swords of Armageddon*, vol. 5 (Chukelea Publications: Sunnyvale, CA, 2007), p. 473.

[21] Hansen (note 20), pp. 96–97.

[22] Kelley, R., 'North Korea's sixth nuclear test: what do we know so far?', SIPRI Expert Comment, 5 Sep. 2017.

Table 6.16. Estimated number of nuclear explosions, 1945–2017

	USA[b]		Russia/ USSR		UK[b]		France		China		India		Pakistan		North Korea		
Year[a]	a	u	a	u	a	u	a	u	a	u	a	u	a	u	a	u	Total
1945	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3
1946	2[c]	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2
1948	3	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3
1949	–	–	1	–	–	–	–	–	–	–	–	–	–	–	–	–	1
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
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
1990	–	8	–	1	–	1	–	6	–	2	–	–	–	–	–	–	18
1991	–	7	–	–	–	1	–	6	–	–	–	–	–	–	–	–	14
1992	–	6	–	–	–	–	–	–	–	2	–	–	–	–	–	–	8

	USA[b]		Russia/ USSR		UK[b]		France		China		India		Pakistan		North Korea		
Year[a]	a	u	a	u	a	u	a	u	a	u	a	u	a	u	a	u	Total
1993	–	–	–	–	–	–	–	–	–	1	–	–	–	–	–	–	1
1994	–	–	–	–	–	–	–	–	–	2	–	–	–	–	–	–	2
1995	–	–	–	–	–	–	–	5	–	2	–	–	–	–	–	–	7
1996	–	–	–	–	–	–	–	1	–	2	–	–	–	–	–	–	3
1998	–	–	–	–	–	–	–	–	–	–	–	2[e]	–	2[e]	–	–	4
2006	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1
2009	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1
2013	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1
2016	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	2	2
2017	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	1
Subtotal	**217**	**815**	**219**	**496**	**21**	**24**	**50**	**160**	**23**	**22**	–	**3**	–	**2**	–	**6**	
Total	**1 032**		**715**		**45**		**210**		**45**		**3**		**2**		**6**		**2 058**

– = no known test; a = atmospheric (or in a few cases underwater); u = underground[f]; USSR = Soviet Union.

[a] The table includes only those years in which a known explosion took place.

[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] One of these tests was carried out underwater.

[d] Two of these tests were carried out underwater.

[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.

[f] '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 kilometres 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 kilometres' (Article II(c)).

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 Comprehensive Nuclear-Test-Ban Treaty Organization (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 Centre (VNIIEF): Sarov, 1996); and Natural Resources Defense Council, 'Archive of nuclear data', various years.

The estimated number of nuclear explosions, 1945–2017

Since 1945 there have been 2058 known nuclear explosions carried out by eight states—the USA, 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 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.[23] It does not include subcritical experiments that did not sustain a nuclear chain reaction. Simultaneous detonations, also known as salvo explosions, were carried out by the USA (from 1963) and the Soviet Union (from 1965), mainly for economic reasons.[24] A total of 20 per cent of the Soviet tests and 6 per cent of the US tests were salvo experiments.

No verified nuclear tests have been carried out by Israel. There are assertions that the unexpected ‘double flash’ registered by the US Vela 6911 satellite in September 1979 was an indication of a nuclear weapon test conducted by Israel with support from South Africa. However, this assertion has never been officially confirmed by either government.[25]

A number of moratoriums on testing, both voluntary and legal, have been observed. The Soviet Union, the UK and the USA observed a moratorium from November 1958 to September 1961. The 1963 Partial Test-Ban Treaty (PTBT), which prohibits nuclear explosions in the atmosphere, in outer space and underwater, entered into force on 10 October 1963.[26] 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.[27]

[23] 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 either no or a very small release of fission energy. The UK has also carried out numerous safety tests but they are not included in table 6.16.

[24] The Soviet Union conducted simultaneous tests of up to 8 devices on 23 Aug. 1975 and 24 Oct. 1990 (the last Soviet test).

[25] Weiss, L., ‘Flash from the past: why an apparent Israeli nuclear test in 1979 matters today’, *Bulletin of the Atomic Scientists*, 8 Sep. 2015.

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

[27] China, France, Russia, the UK and the USA are among the parties. For a full list see annex A, section I, in this volume.