2. Nuclear explosions

RICHARD W. FIELDHOUSE and ROBERT S. NORRIS;
appendix prepared by RAGNHILD FERM

Superscript numbers refer to the list of notes and references at the end of the chapter.

I. Nuclear explosions and the test debate

Nuclear weapon testing issues have been thrust once more to the front of the arms control and nuclear weapon debates in recent years. This is due to the widespread international interest in a comprehensive test ban (CTB) and to the current differences between the USA and the USSR on nuclear weapon testing. Since the USSR began its moratorium on nuclear tests in August 1985, the USA has come under increasing pressure, both domestic and international, to stop testing or, at a minimum, to resume negotiations with the Soviet Union on a CTB. Unfortunately, the large amount of attention paid to nuclear testing has not brought with it an equal amount of reliable factual information on which to debate the issues. Numerous questions are currently disputed, such as: Are nuclear explosions necessary to maintain existing stockpiles, to develop new nuclear weapon designs, or not at all? Is it possible, as posited by previous US Administrations, to maintain nuclear weapons under a CTB regime? Is it possible to verify compliance with a CTB?

Although both the USA and the USSR have made scores of official public statements about nuclear testing and test limitations, neither government has done much to clarify these issues. On the contrary, both governments have presented information in such a way as to confuse the issues. Nor have the other three nuclear testing nations contributed to clarity: the UK sides with the USA; France is opposed to any test limitations and China has generally remained aloof from the debate. This leaves the public as confused today as it was before nuclear testing issues regained their current prominence.

Each year since 1969, the *SIPRI Yearbook* has provided fundamental information about nuclear explosions: which nations have detonated which number of nuclear explosions, where and when they have taken place and, whenever possible, an estimate of the size, or yield, of the explosions. Most explosions are tests of nuclear weapons; the USSR has conducted some explosions for non-military purposes, the so-called peaceful nuclear explosions (PNEs), as recently as 1985. Although it is possible to detect all underground nuclear explosions above a certain yield, it is almost impossible to learn more than a few basic facts about each test: the time, place and relative magnitude of each event. The nuclear weapon states conduct their nuclear weapon activities with utmost secrecy to prevent others from learning details of their nuclear warheads and weapon systems. These are among the most closely guarded military secrets in the world. Consequently one does not know the exact yield of an explosion, for what purpose it was conducted, or what relation it has, if

any, to weapons in a nation's stockpile or in development. Thus, while the public has a good record of the number of nuclear explosions, it has almost no knowledge of the most important details: What is the significance of the tests and can they be stopped? By improving and studying the available information on nuclear tests a clear understanding could be gained and used to move forward on the task of limiting and ceasing nuclear explosions.

This chapter discusses the most important sources of information on nuclear explosions, and explains the problems and limitations of such information and, therefore, the need to revise the data as new information becomes available. It concludes with a review of the nuclear explosions and related issues of 1986.

II. Information on nuclear explosions

The five nuclear weapon states (the USA, the USSR, France, the UK and China) are currently capable of conducting explosions for nuclear weapon tests. The USA, the USSR and the UK are signatories of the Partial Test Ban Treaty (PTBT) of 1963, prohibiting nuclear explosions in environments other than underground. Although France and China have not signed the PTBT, both nations have announced that they intend not to test nuclear weapons in the atmosphere. The Chinese announcement that they 'will no longer conduct atmospheric tests in the future' was made by Premier Zhao Ziyang on 21 March 1986. Thus it is possible that the Chinese atmospheric nuclear test conducted in 1980 was the last of its kind by any nation.

The simplest way to obtain information about nuclear tests would be for the five nuclear weapon states to announce their own tests, as recommended by a 1986 UN General Assembly resolution.[1] However, each of these five nations has its own different policy regarding information about its nuclear testing programme; all of them employ secrecy to a greater or lesser extent. Although the USA is the most open with information about its tests, it has not publicly announced every US test and has adopted an explicit policy not to announce some of its lower-yield tests.[2] It has now made public all tests conducted before the signing of the PTBT in 1963, although at the time many were not announced. According to the US Department of Energy, 'Some tests conducted underground since the signing of the treaty [PTBT] and designed to be contained completely have not been announced. Information concerning these events is classified'.[3]

The USSR generally has not made public any information about its nuclear tests, except for some peaceful nuclear explosions and some of its early atmospheric tests. In 1986, the USSR publicly stated for the first time the number of nuclear explosions it conducted during the year—nine—in a comparison of the US and Soviet testing programmes.[4] In another unusual move, the USSR has reported on the number of US tests during the Soviet moratorium period. On 19 December, *Pravda* reported that the USA had conducted 24 tests, 4 of which the USA had not announced.

Since 1962, the UK has conducted all its nuclear tests jointly with the USA at the US Nevada Test Site (NTS) and all have apparently been reported

afterwards by the UK and the USA. France has occasionally discussed its tests, but has not done so regularly. The current French policy is not to announce any tests; French tests are usually reported afterwards by seismologists in New Zealand. China publicly discussed only a few of its atmospheric nuclear tests between 1964 and 1980, especially those successful tests that represented development milestones in the Chinese nuclear weapon programme. The Chinese Government has the policy of neither confirming nor denying its nuclear explosions. In 1986 several official Chinese publications stated that China had conducted 32 nuclear tests since 1964, 3 more than available data suggest.[5] It seems likely that this figure is quoted from foreign sources.

On those occasions when a government has provided public information about a test, the information has been limited, usually to only the date of the explosion, its general location and (less frequently) the general explosive yield or yield range. The current US yield range estimates are rarely useful: either less than 20 kt or 20–150 kt. The USA also usually provides the names and the general purpose of its announced tests, that is, to test weapon effects, designs, safety, reliability, and so on. No government provides details about the specific purposes of its tests, or their exact size; these matters are considered by all countries to be military secrets. Thus, information provided by the testing nations about their tests leaves the picture incomplete. A most revealing fact about the difficulty of obtaining reliable information is that the total number of nuclear tests by the five countries is still not known.

Sources of information

When a nuclear explosive is detonated it releases energy in forms that can often be detected from long distances. Nuclear explosions that take place underground cause seismic shocks much like small earthquakes. It is essentially the same phenomenon of ground motion for both events, but with measurably different characteristics. Since the five nuclear weapon states now conduct their nuclear explosions underground, seismic recording devices can measure the ground shocks and thus detect nuclear explosions and earthquakes alike at intercontinental distances. Seismic detection is the chief means by which underground nuclear explosions can be detected and identified. Numerous government- or university-affiliated seismic observatories gather and share data on seismic shocks from nuclear tests. From these data it is possible to assemble a fair picture of the nuclear testing activities of all five nuclear weapon nations. Some governments operate seismic detection networks for intelligence purposes; their information is not usually made public.

A number of seismic observatories offer their information for public and scientific use, to contribute to better knowledge of nuclear testing. Most prominent among these institutions is the Hagfors Observatory of the Swedish National Defence Research Institute, known by its Swedish initials as FOA. FOA produces the most regular and complete lists available from any government of known and presumed nuclear explosions world-wide. FOA uses data from its own seismic network and those from other observatories, comparing data and updating its lists. Numerous other institutions, such as

those in New Zealand and Norway and the Australian Seismological Centre which opened in September 1986, are co-operating in efforts to establish a world-wide seismic monitoring system. Most of the seismic data exchanged by such institutions are incomprehensible to the nonspecialist, although several institutions translate these data into understandable lists of nuclear explosions or seismic events.

Among the other primary sources of information are the US Department of Energy (DOE), the US Defense Nuclear Agency (DNA) and the US Geological Survey (USGS). DOE, and its predecessor agencies (the Atomic Energy Commission and the Energy Research and Development Administration), have been the largest single source of information on nuclear tests. DOE is the US agency responsible for the US nuclear weapon test programme and, along with other agencies, for intelligence about other nations' nuclear weapon and test programmes. DOE obtains information on non-US nuclear explosions through the Atomic Energy Detection System (AEDS), a network of sensors operated by the Air Force Technical Applications Center (AFTAC) across and above the earth.[6] Through DOE, the USA has produced information about most US nuclear tests and a large portion of non-US nuclear explosions.[7] DNA is the US Department of Defense agency responsible for research on nuclear weapon effects. It recently published 42 volumes on US nuclear tests from the 1940s to the 1960s for its Nuclear Test Personnel Review programme.[8] The USGS is part of the US Department of the Interior and is concerned with, among other things, recording seismic activity for an understanding of earthquake behaviour. The USGS publishes a monthly report called 'Preliminary Determination of Epicenters' which lists records of world-wide seismic activity. Using this information it is possible to study potential nuclear explosions.

As a result of these and other sources, scientific evidence is available to provide additional information about nuclear tests. However, this seismic information is still not enough to provide a complete picture of nuclear testing; the current system cannot fill some of the gaps.

Problems with information

Even today's world-wide seismic detection capabilities can only provide a limited amount of information about nuclear explosions: the location, time and usually the approximate size of the event. It is not possible to know the precise yield of nuclear explosions (estimates are made), and seismic means cannot distinguish between a large chemical explosion and a very small nuclear one. Thus some nuclear tests may escape detection or may be too ambiguous to be classified as nuclear explosions. Several recent examples are illustrative.

On 11 July 1985, weak seismic signals were recorded coming from the area of the Soviet nuclear weapon test site at Semipalatinsk. The USA reported that the signals were proof of a very low yield (sub-kiloton) Soviet nuclear explosion that was only detectable by a new seismic array located near enough to the test site to receive high-frequency seismic signals. High-frequency signals are best able to discriminate between earthquakes and man-made explosions, but can

only be accurately recorded at regional distances—up to 3000 km, depending on the geological conditions. The USA had information from such a system, the Norwegian Regional Seismic Array System (NORESS), that is operated by Norway in co-operation with the USA as part of a joint US–Norwegian seismic detection system.[9] The Hagfors Observatory did not detect or report the signals as having come from a nuclear explosion, reportedly because of problems with their computer equipment.[10] Consequently, there were differences in the estimates of Soviet nuclear explosions for 1985. Breaking with past practice, the USSR reported on 2 April 1986 that it had conducted nine nuclear explosions in 1985, thus confirming that more explosions had occurred than were agreed within the seismological community. The standard seismic networks had not properly identified the explosion.

In addition to questions about the exact number of tests there is also uncertainty as to their size. It is difficult, if not impossible, to know the exact yield of a nuclear explosion because of the problems involved in measuring precisely the energy released. Governments have a variety of methods for measuring and estimating their own nuclear tests; the problem is compounded when estimating the yields of foreign nuclear explosions. For example, the US Government, even with its sophisticated technology, is unsure of the exact size of Soviet nuclear explosions. This is because of uncertainties about the geologic formation of the primary Soviet nuclear weapon test site. If this were known in better detail more accurate estimates of the size of Soviet nuclear weapon tests could be made. The USA used a yield-estimating formula for many years that many experts said inflated the true yield. That formula was changed in 1986 (see below).

III. Nuclear explosions and test-related issues in 1986

According to available information, there were 23 nuclear test explosions in 1986. This is the lowest number of nuclear tests since 1960. The USSR did not conduct any tests during the year, as General Secretary Gorbachev extended the Soviet test moratorium four times, until 1 January 1987. The United States conducted 14 tests, France 8 and the United Kingdom 1 jointly with the USA. China did not conduct any nuclear tests during 1986.

During 1986, the issues surrounding nuclear testing remained prominent and contentious. The two superpowers mostly talked past one another as they pursued and presented their agendas. The USA focused its proposals on enhanced verification measures to the unratified 1974 Threshold Test Ban Treaty (TTBT) and the unratified 1976 Peaceful Nuclear Explosions Treaty (PNET) and showed no interest in a CTB. The Soviet Union initially rejected US proposals linked to the TTBT, but then agreed at the Reykjavik summit meeting to discuss all testing issues with the USA.

As part of a set of broad proposals to eliminate nuclear weapons by the year 2000, General Secretary Gorbachev extended the Soviet unilateral test moratorium on 15 January 1986 until the end of March. On 26 February the US House of Representatives passed a non-binding resolution by a vote of 268 to

148 calling on President Reagan to submit the TTBT and the PNET to the Senate for ratification.

On 13 March, Gorbachev announced, in a response to the leaders of the Six-Nation Peace Initiative (Argentina, Greece, India, Mexico, Sweden and Tanzania), that the Soviet moratorium would continue past 31 March for as long as the USA refrained from testing. On the following day President Reagan repeated a previous proposal to begin bilateral negotiations with the USSR to improve verification of the TTBT and the PNET. He also renewed his offer to have Soviet scientists observe and measure a US test at the Nevada Test Site in late April.

The USA conducted its first nuclear test of 1986 on 22 March, bringing an immediate protest from the USSR. Attention then focused on the next US test after 31 March, since it was expected to trigger the end of the Soviet moratorium. After being postponed twice, the test (code-named Mighty Oak) was finally conducted on 10 April. The initial Soviet response declared on 11 April 'that from now on it [the USSR] is free from the unilateral commitment made by it to refrain from conducting any nuclear explosions'.[11] But in a television speech on 14 May concerning the Chernobyl nuclear reactor accident of 26 April, Gorbachev extended the test moratorium a third time, to 6 August. In a television address on 18 August, Gorbachev extended the moratorium a fourth time, until 1 January 1987, emphasizing that an agreement ending nuclear tests could be signed at a US–Soviet summit meeting, and thus be the prologue to further progress in other arms control areas. On 18 December, the Soviet news agency TASS reported that the Soviet Union would abandon its moratorium after the first US test of 1987, reportedly scheduled for 29 January.

During the year the United States and the Soviet Union held three meetings of experts in Geneva to discuss the full range of US–Soviet testing issues, including verification measures and a CTB. The first session was held from 25 July to 1 August. A second session was held from 4 to 18 September and the third from 2 to 25 November. Because of the wide differences between the two countries on nuclear testing little progress was made.

In a surprising development, on 8 August the US House of Representatives passed by a 234–155 vote a binding amendment to the DOD Authorization Bill which would impose a one-year moratorium on all US nuclear tests larger than 1 kt beginning on 1 January 1987, contingent upon Soviet agreement to on-site inspection.[12] The day before, the US Senate had passed a non-binding resolution by a 64–35 vote calling for a resumption of CTB negotiations.[13] In a letter to Senator Goldwater on 10 October, the President pledged to ask for Senate ratification of the TTBT and the PNET if the Soviet Union would agree to 'essential' verification procedures before ratification proceedings begin. However, even if the Soviet Union fails to agree to such procedures, the President pledged still to make ratification a first order of business with the new Senate, but with the proviso that the treaties would not take effect until they are 'effectively verifiable'.[14]

As a result of congressional and public pressure to make progress towards test limitations, the Reagan Administration responded with numerous arguments for the need to continue testing.[15] The arguments often contradicted

long-held assessments of the impact of a CTB. For example, for years a basic assumption about a CTB had been that it would help prevent or slow down the horizontal proliferation of nuclear weapons. The Administration argues the opposite, stating that if doubts were raised about US nuclear guarantees to its allies under a CTB, it would encourage the proliferation of nuclear weapons. According to Administration officials, another adverse effect of a CTB would be an increase in the number of warheads and the megatonnage in the US stockpile. This would occur, they argue, to compensate for the uncertainties surrounding their reliability. Such arguments were not subject to proper public debate because the US Government limited itself to making the assertions but not substantiating them, on the grounds that such details are classified.

On 21 January 1986, William J. Casey, then Director of Central Intelligence, formally approved changes in the procedures used to estimate the yields of large Soviet tests.[16] For several years an intense debate has occurred among seismologists and government intelligence officials over whether the most accurate formula was being used to calculate the yields of Soviet tests. Because of insufficient knowlede of the geologic composition of the Soviet test sites, various assumptions have been made which have led to different conclusions about the size of the tests. The calculation formula includes an 'adjustment factor' to account for the geology near Soviet test sites. This factor has been disputed for years and was increased to reflect revised assumptions about the geology in question. The change may reduce earlier yield estimates by some 20 per cent.[17] The issue is important because the Reagan Administration has frequently alleged that the Soviet Union has violated the TTBT by conducting tests above the 150-kt yield limit set by the TTBT.

In early July US seismologists began to install three seismic monitoring stations near the main Soviet test site south-west of Semipalatinsk. This came about as a result of an agreement between the private US Natural Resources Defense Council and the Soviet Academy of Sciences, signed on 28 May.[18] The seismic equipment began operating on 10 July and continuously provided information on seismic activity in the area throughout the rest of the year. (This information should be of great interest whether or not the USSR conducts any nuclear explosions, because so little is known outside the Soviet Union about the geology around the test site.) Such seismic information may improve US understanding of the geology to the extent that it can resolve the US allegation that the USSR has violated the 150-kt yield limit of the TTBT.

Notes and references

[1] United Nations, General Assembly, Resolution 41/59N, 'Notification of nuclear tests'.

[2] Cochran, T. B., Norris, R. S., Arkin, W. M. and Hoenig, M. M., 'Unannounced US nuclear weapons tests: 1980–1984', *Nuclear Weapons Databook*, Working Paper 86-1 (Natural Resources Defense Council: Washington, DC, Jan. 1986), p. 1.

[3] US Department of Energy, *Announced United States Nuclear Tests, July 1945 through December 1984*, Report Number NVO-209 (Rev. 5), (DOE Nevada Operations Office: Las Vegas, NV, 1985), p. i.

[4] 'The USA is seeking nuclear superiority', TASS, 2 Apr. 1986, English transcript dated 4 Apr.

[5] Previously, 29 tests had been identified with specific dates (see *SIPRI Yearbook 1986*, p. 102) and a 30th test was reported to have taken place. See Ku, M., 'Deng Jiaxiang: China's father of A-Bomb', *Beijing Review*, vol. 29, no. 32 (11 Aug. 1986), p. 22.

[6] For a description of the AEDS and the intelligence network that supports it, see Richelson, J. R., *The US Intelligence Community* (Ballinger: Cambridge, MA, 1985), pp. 56–8, 156–62.

[7] See US Department of Energy, *Announced United States Nuclear Tests, July 1945 through December 1985*, Report Number NVO-209 (Rev. 6), (DOE Nevada Operations Office: Las Vegas, NV, 1986); and 'Foreign nuclear detonations through December 31 1984', computer printout from DOE Nevada Operations Office dated 22 May 1985. The DOE Nevada Operations Office stated in a letter of November 1985 that 'this office no longer maintains lists or records in any form of foreign nuclear detonations'.

[8] For a list of these reports, see Norris, R. S., Cochran, T. B. and Arkin, W. M., 'Known US nuclear tests July 1945 to 16 October 1986', *Nuclear Weapons Databook*, Working Paper 86–2 (Rev. 1) (Natural Resources Defense Council: Washington, DC, Oct. 1986), p. 49.

[9] See SIPRI, *World Armaments and Disarmament: SIPRI Yearbook 1986* (Oxford University Press: Oxford, 1986), p. 123; 'NORSAR: Norwegian Seismic Array', undated brochure; 'Norwegian Regional Seismic Array System: NORESS', brochure dated 5 June 1985 from NORSAR.

[10] Swedish Foreign Affairs Minister Sten Andersson reported that the Hagfors Observatory 'observed an explosion on that day but the information necessary for registering and analysing it was not available on account of the computer breakdown. We can almost certainly say that we would have reported the test if the computer had functioned'. Swedish Ministry for Foreign Affairs, Interpellation No. 1985/86:167, Press Release, 20 May 1986.

[11] Soviet Embassy, Washington, DC, Press Release, 14 Apr. 1986, Soviet Government Statement.

[12] US Congress, *Congressional Record*, 8 Aug. 1986, pp. H5738–56.

[13] US Congress, *Congressional Record*, 7 Aug. 1986, pp. S10714–36.

[14] US Congress, *National Defense Authorization Act for Fiscal Year 1987*, Conference Report, House Report 99–1001, pp. 516–17.

[15] See, for example, Senate Foreign Relations Committee hearings of 8 May, 19 and 26 June 1986, and Senate Armed Services Committee hearings of 29–30 Apr. 1986; Wagner, R., letter to the *Washington Post*, 22 Mar. 1986, p. A26; and US Department of State, 'US policy regarding limitations on nuclear testing', *Special Report No. 150* (State Department: Washington, DC, Aug. 1986).

[16] Gordon, M. R., 'CIA changes way that it measures Soviet atom tests', *New York Times*, 2 Apr. 1986, p. A1.

[17] 'CIA lowers estimates of Soviet test yields', *Arms Control Today*, Apr. 1986, p. 21.

[18] Broad, W. J., 'US group checks Soviet atom site', *New York Times*, 14 July 1986, p. A1; and 'Monitoring nuke tests', *Newsweek*, 28 July 1986, p. 33.

Appendix 2A. Nuclear explosions, 1945–86

Table 2A.1 Nuclear explosions in 1986 (preliminary data)

Date[a]	Latitude (deg)	Longitude (deg)	Region	Body wave magnitude[b]
USA				
22 Mar.	37.083 N	116.066 W	Nevada	5.7
10 Apr.	37.218 N	116.183 W	Nevada	5.3
20 Apr.	37. N	116. W	Nevada	
22 Apr.	37.264 N	116.440 W	Nevada	5.4
21 May	37.125 N	116.060 W	Nevada	
5 June	37.098 N	116.016 W	Nevada	5.5
17 July	37.279 N	116.356 W	Nevada	
24 July	37.143 N	116.071 W	Nevada	
4 Sep.	37. N	116. W	Nevada	
11 Sep.	37.069 N	116.050 W	Nevada	
30 Sep.	37.300 N	116.307 W	Nevada	
16 Oct.	37.220 N	116.462 W	Nevada	5.6
14 Nov.	37.100 N	116.048 W	Nevada	5.8
13 Dec.	37.263 N	116.412 W	Nevada	5.7
UK				
25 June	37.265 N	116.499 W	Nevada	5.5
France				
26 Apr.	22.15 S	139.12 W	Mururoa	4.8
6 May	22. S	139. W	Mururoa	4.8
27 May	22. S	139. W	Mururoa	4.7
30 May	21.898 S	139.026 W	Mururoa	5.4
10 Nov.	22. S	139. W	Mururoa	4.9
12 Nov.	21.860 S	139.080 W	Mururoa	5.3
6 Dec.	22. S	139. W	Mururoa	5.0
10 Dec.	21.899 S	138.934 W	Mururoa	5.5

[a] The dates are all according to Greenwich Mean Time.

[b] Body wave magnitude (m_b) indicates the size of the event. m_b data for the US and British tests were provided by the Hagfors Observatory of the Swedish National Defence Research Institute (FOA); data for the French tests were provided by the New Zealand Seismological Observatory.

Table 2A.2. Estimated number of nuclear explosions 16 July 1945–5 August 1963 (the signing of the Partial Test Ban Treaty)

a = atmospheric
u = underground

	USA		USSR		UK		France		
Year	a	u	a	u	a	u	a	u	Total
1945	3	0							**3**
1946	2[a]	0							**2**
1947	0	0							**0**
1948	3	0							**3**
1949	0	0	1	0					**1**
1950	0	0	0	0					**0**
1951	15	1	2	0					**18**
1952	10	0	0	0	1	0			**11**
1953	11	0	4	0	2	0			**17**
1954	6	0	7	0	0	0			**13**
1955	17[a]	1	5[c]	0	0	0			**23**
1956	18	0	9	0	6	0			**33**
1957	27	5	15[c]	0	7	0			**54**
1958	62[b]	15	29	0	5	0			**111**
1949–58, exact years unknown			18						**18**
1959	0	0	0	0	0	0			**0**
1960	0	0	0	0	0	0	3	0	**3**
1961	0	10	50[a]	1	0	0	1	1	**63**
1962	38[a]	58	43	1	0	2	0	1	**143**
1 Jan.–5 Aug. 1963	4	25	0	0	0	0	0	2	**31**
Total	**216**	**115**	**183**[c]	**2**	**21**	**2**	**4**	**4**	**547**

[a] At least one of these tests was carried out under water.
[b] Two of these tests were carried out under water.
[c] The total figure for Soviet atmospheric tests includes the 18 additional tests conducted in the period 1949–58, for which exact years are not available.

Table 2A.3. Estimated number of nuclear explosions 6 August 1963–31 December 1986

a = atmospheric
u = underground

	USA[a]		USSR		UK[a]		France		China		India		
Year	a	u	a	u	a	u	a	u	a	u	a	u	Total
6 Aug.–31 Dec.													
1963	0	14	0	0	0	0	0	1					**15**
1964	0	29	0	6	0	1	0	3	1	0			**40**
1965	0	29	0	9	0	1	0	4	1	0			**44**
1966	0	40	0	15	0	0	5	1	3	0			**64**
1967	0	29	0	17	0	0	3	0	2	0			**51**
1968	0	39[b]	0	13	0	0	5	0	1	0			**58**
1969	0	29	0	16	0	0	0	0	1	1			**47**
1970	0	33	0	17	0	0	8	0	1	0			**59**
1971	0	15	0	19	0	0	5	0	1	0			**40**
1972	0	15	0	22	0	0	3	0	2	0			**42**
1973	0	12[c]	0	14	0	0	5	0	1	0			**32**
1974	0	12	0	19	0	1	7	0	1	0	0	1	**41**
1975	0	17	0	15	0	0	0	2	0	1	0	0	**35**
1976	0	15	0	17	0	1	0	1	3	1	0	0	**38**
1977	0	12	0	18	0	0	0	6	1	0	0	0	**37**
1978	0	16	0	28	0	2	0	7	2	1	0	0	**56**
1979	0	15	0	29	0	1	0	9	0	0	0	0	**54**
1980	0	14	0	21	0	3	0	11	1	0	0	0	**50**
1981	0	16	0	22	0	1	0	10	0	0	0	0	**49**
1982	0	18	0	31	0	1	0	5	0	0	0	0	**55**
1983	0	17	0	27	0	1	0	7	0	1	0	0	**53**
1984	0	17	0	28	0	2	0	8	0	2	0	0	**57**
1985	0	17	0	9	0	1	0	8	0	0	0	0	**35**
1986	0	14	0	0	0	1	0	8	0	0			**23**[d]
Total	**0**	**484**	**0**	**412**	**0**	**17**	**41**	**91**	**22**	**7**	**0**	**1**	**1075**

[a] See note *a* below.
[b] Five devices used simultaneously in the same test are counted here as one explosion.
[c] Three devices used simultaneously in the same test are counted here as one explosion.
[d] The data for 1986 are preliminary.

Table 2A.4. Estimated number of nuclear explosions 16 July 1945–31 December 1986

USA[a]	USSR	UK[a]	France	China	India	Total
815	597	40	140	29	1	**1622**

[a] All British tests from 1962 have been conducted jointly with the United States at the Nevada Test Site. Therefore, the number of US tests is actually higher than indicated here.

Sources for tables 2A.1–2A.4

Swedish National Defence Research Institute (FOA), various estimates; Norris, R. S., Cochran, T. B. and Arkin, W. M., 'Known US nuclear tests July 1945 to 16 October 1986', *Nuclear Weapons Databook*, Working Paper no. 86-2 (Rev. 1) (Natural Resources Defense Council: Washington, DC, Oct. 1986); Sands, J. I., Norris, R. S. and Cochran, T. B., 'Known Soviet nuclear explosions, 1949–1985', *Nuclear Weapons Databook*, Working Paper no. 86-3 (Rev. 2 June 1986) (Natural Resources Defense Council: Washington, DC, Feb. 1986); Department of Scientific and Industrial Research (DSIR), Geophysics Division, New Zealand, various estimates; and US Geological Survey.