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French Nuclear Testing, 1960-1988

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Introduction

Since 1960, France has conducted at least 172 nuclear tests (see Tables 1 and 2). Through 1988, French tests account for about 9.6 percent of all nuclear tests conducted since 1945.[1]

The largest number of tests in any one year was 13 in 1980. There has been only one year (1969) when there were no tests. Over the past 28 years, France has conducted an average of 5.9 tests per year, and is currently testing at the rate of eight per year.

On average since 1960, around 20 nuclear tests have been required for each type of nuclear weapon in the French arsenal, compared with 6-8 tests for each modern type of U.S. warhead. These 172 French tests have supported the production of approximately 800 nuclear warheads since 1963, and continue to support the current stockpile of almost 500 deployable warheads. The majority of tests, 39 atmospheric and 108 underground, have been conducted at the Mururoa atoll in the Pacific.

The total cumulative yield of all 172 tests is estimated to be 12.55 megatons (Mt), with the 48 atmospheric tests accounting for 10 Mt of this total.[2] The largest explosion was 2.6 Mt on 24 August 1968 at Fangataufa. The yields of underground tests at the Pacific Test Center have varied greatly, ranging from below 1 kiloton (kt), up to 150 kt. The cumulative yield of all underground tests in the Pacific from 1975 through 1988 is estimated at 2200 kt.

French testing can be divided into four distinct periods, broken down by date and location:

- 1960-1961: 4 atmospheric tests in Algeria;
- 1961-1966: 13 underground tests in Algeria;
- 1966-1974: 44 atmospheric tests at the Pacific Test Center, 39 over Mururoa, 5 over Fangataufa;
- 1975-1988: 111 underground tests at the Pacific Test Center, 108 at Mururoa, 3 at Fangataufa.

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[1] About 1793 nuclear tests have been conducted worldwide by six countries since 1945. Since 1960 (the start of French testing), France has accounted for 11.3 percent of worldwide testing.

[2] DIRCEN, "Dossier no. 1" (short title), Table 7/41.

The purpose of future French nuclear testing is to develop a number of new nuclear weapon systems planned for deployment in the 1990s, including: the TN 35 warhead for the S4 Intermediate-Range Ballistic Missile (IRBM); the TN 75 warhead for the M45 Submarine-Launched Ballistic Missile (SLBM); the TN 76 warhead for the M5 SLBM; the Enhanced Radiation Warhead (ERW, or neutron bomb) and a standard fission warhead for the Hadès missile; and possibly a nuclear depth bomb for use by the Navy.

Reliability of estimates/Sources of information

France has not made a practice of announcing all their nuclear tests, which leaves some uncertainty about the total number conducted since 1960.

During the 1960s and early 1970s, France conducted 48 atmospheric tests, four in Algeria, the rest in the Pacific. As these atmospheric tests were inherently difficult to conceal, the French routinely issued a statement following each series, often indicating the purpose and estimated yield of each test.[3] The dates, yields, and location of the 13 underground tests in Algeria between 1961 and 1966 are fairly well documented, due in part to the fact that they were also studied for possible peacetime application.

Since France began testing underground in the Tuamotu Archipelago in the South Pacific in 1975, a veil of secrecy has been lowered over the whole testing program, due in part to the continued opposition expressed by virtually all Pacific nations. This working paper has relied upon various scientific institutions, foremost the New Zealand Department of Scientific and Industrial Research (DSIR) and the Swedish National Defence Research Institute (FOA), which independently record and analyze seismic data, and have reported the epicenter, origin time, and magnitude of most of these tests.

In October 1985, the French government office in charge of nuclear testing (DIRCEN), in response to a query from NRDC, released a publication which summarized the number of French tests from 1960 through 1984.[4] The total was 138, 11 more than previously thought. The total number of atmospheric tests

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[3] In addition, prior to each test France was required to issue public maritime and aeronautical warnings to ships and aircraft in the vicinity of the test site.

[4] DIRCEN (Direction des Centres d'Expérimentations Nucléaires), "Dossier no. 1," Table 7/41: Essais Nucléaires: Tableau Recapitulatif des Explosions Annoncées et Presumées.

conducted was 48, three more than previously thought.[5] Underground tests totalled 90, eight more than previous totals. Of these eight, five were not detected by any source, including DSIR and FOA; two during 1975-1977, two in 1980, and one in 1981.[6]

Further examination of the seismological records of the Geological Survey of Canada and the DSIR have revealed two additional underground tests in 1983.[7] These two very low-yield tests, previously undetected, are in addition to the five mentioned above.

It is not known whether undetected tests have occurred since the release of the DIRCEN document. The director of DIRCEN stated in October 1985 that the French will conduct eight tests per year on average,[8] the number that in fact has been "detected" each year since 1984. Foreign Minister Roland Dumas announced in 1988 that France would henceforth announce at the end of each year the number of nuclear tests it has conducted over the previous 12 months.[9]

Early preparations

Following the official decision of 1954 to construct an atomic bomb, the French began to look for a suitable test site. Possible locations included the Kerguelen Islands in the Indian Ocean, Clipperton Island and the Tuamotu Archipelago in the Pacific Ocean, and French Algeria. Clipperton and the Tuamotu Archipelago were ruled out for lack of an airfield. The Kerguelen Islands were too far away and had poor weather. This left French Algeria.[10] In

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[5] These three extra tests occurred in 1966, 1971, and 1974 (see Table 1).

[6] All that is known about these tests is the year in which they were conducted. They have been included in Table 1 (see 1977 entry for the two extra tests during 1975-77).

[7] "Scientists Confirm Bomb Tests," *New Zealand Herald*, 13 May 1988.

[8] See quote by General Mermet; Jacques Isnard, "L'enjeu de l'Indépendance Nationale," *Le Monde*, 25 October 1985.

[9] Speaking at the United Nations' third special session on disarmament; French Embassy Press and Information Service (Washington, D.C.), *News from France*, Vol. 88.11, 14 June 1988, p. 2.

[10] General Ailleret, *L'Aventure Atomique Français* (Paris: Grasset, 1968), p. 228.

1957 the Reggane site was chosen, and in April 1958 the French government set a goal to conduct the test in the first quarter of 1960.[11]

To help prepare for France's first nuclear test, several French delegations came to the U.S. Nevada Test Site (NTS) in 1957 and 1958 to witness and participate in U.S. nuclear tests. These visits provided an orientation in nuclear test effects, culminating in the participation in the U.S. atmospheric test SMOKY on 31 August 1957, at which the French tested a selection of their underground personnel shelters, equipment, and test instrumentation. The importance of these visits was reflected in the high-ranking French delegates, which included General Charles Ailleret, often referred to as the father of the French atomic bomb, and General Andre Buchalet, founder and first director of the Military Applications Branch (DAM) of the French Atomic Energy Commission (CEA).[12]

Testing in French Algeria

The first French nuclear test, codenamed GERBOISE BLEUE, occurred on 13 February 1960 from a 344 foot (105 meter) tower near Reggane, Algeria.[13] At 60-70 kt, the yield of this plutonium device was three times the first U.S. or British test. Three further less powerful atmospheric tests were conducted at the Reggane site in 1960 and 1961. All were pure plutonium fission devices,

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[11] Commissariat à l'Énergie Atomique (CEA), "Les Principales Activités du Commissariat à l'Énergie Atomique," *CEA Notes d'Information*, report no. 33 971, January 1970, p. 15.

[12] U.S. AEC, press release LAV-58-17, dated 17 February 1958, released under the Freedom of Information Act (FOIA).

[13] An official announcement on the day of France's first test stated that "although France's final aim is disarmament... the failure of disarmament talks up to now led the French government to provide its military forces with atomic weapons"; French Embassy Press and Information Service (N.Y.), "France's First Atomic Explosion," release no. 886, 13 February 1960, p. 1. Twenty seven years later (1987), the situation was very much the same; the French Prime Minister, Jacques Chirac, in response to a question concerning the possible cessation of French nuclear testing, stated that "We shall stop when the United States and the Soviet Union have the same number of nuclear warheads as us. We shall then be ready to stop, and even also to reduce our nuclear forces"; Jacques Chirac, interview on Soviet television, translated by the French Embassy Press and Information Service (London), 16 May 1987, p. 4.

detonated from towers, and studied for their weapons effects. Following each of these tests, neighboring African countries protested, some even going so far as to temporarily break off diplomatic relations with France.[14] The first French tests, moreover, were held during a U.S.-Soviet-British testing moratorium that began in 1958.

Following the first four atmospheric tests, the French moved the testing program underground. Thirteen tests were carried out from 1961 to 1966 in the Taourirt Tan Afella granite intrusive (also called the Hoggar Massif, see Appendix 1). The yield of these 13 underground tests varied greatly, between 3.6 kt and 127 kt. The military appropriations bill covering the 1960-65 period stated that the goal of the nuclear development program was "the creation of a first system of operational nuclear weapons consisting of Mirage IV bombers carrying a fission bomb with a power equivalent to 50 kt."[15] This weapon was probably the AN 11. These 13 tests purportedly involved the miniaturization of the AN 11 bomb, a prototype of which was successfully tested on 1 May 1962.[16]

Atmospheric testing at Mururoa and Fangataufa

After Algerian independence in 1962, France decided to move their nuclear test program to the uninhabited atolls of Mururoa[17] and Fangataufa in the Tuamotu Archipelago (see Appendix 1). Later that year the Pacific test site was officially established as the Centre d'Expérimentations du Pacifique (CEP).[18]

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[14] Bertrand Goldschmidt, *The Atomic Adventure: Its Political and Technical Aspects*, trans. by Peter Beer (New York: Macmillan Company, 1964), p. 122.

[15] French Embassy Press and Information Service (N.Y.), "The French Nuclear Tests at the Pacific Tests Center," 1972, p. 2.

[16] Goldschmidt, *op. cit.*, p. 155. Full-scale production of the AN 11 commenced in 1963.

[17] Originally the island was called Moruroa, the local traditional name. However it was changed into Mururoa by the French military in the 1960s. Many people opposed to the use of this atoll (or any other Pacific atoll) for French nuclear testing still use the former name of Moruroa.

[18] Appendix 2 provides further details on the CEP and the agencies involved in French nuclear testing.

The 1963 Limited Test Ban Treaty (LTBT), signed in August, banned the testing of nuclear weapons in the atmosphere, underwater, and in outer space. In 1963, however, President de Gaulle officially announced that France would test its nuclear bombs in the atmosphere, using Mururoa atoll. Following the signing of the LTBT, President Kennedy offered U.S. help in the development of the French nuclear program, if France would abandon atmospheric testing. De Gaulle responded that France was not a signatory to the LTBT, and that if help was forthcoming, strings would be attached, thus hampering French independence. Also, France's weaponry was not yet at such an advanced stage that testing could be transferred underground.[19]

Between 1966 and 1974, France conducted 44 atmospheric tests in the Pacific, 39 at Mururoa, and five at Fangataufa. The tests were conducted from barges, balloons, and airdrops from Mirage IVA, Mirage IIIE, and Jaguar A aircraft. From 1965-70 warheads were developed for the S2 IRBM (MR 31 pure fission warhead tested in 1966), for the M1 and M2 SLBMs (MR 41 boosted fission warhead tested in 1968), and for the M20 SLBM and S3 IRBM (TN 60 thermonuclear warhead tested in 1970).

Following the tests of a low-yield fission primary in 1967 and early 1968, France exploded her first two-stage thermonuclear device on 24 August 1968, eight years after its first nuclear test. This first thermonuclear test, codenamed CANOPUS, was also France's largest known explosion to date, at 2.6 Mt. This test was facilitated by the start-up of France's first military uranium enrichment plant at Pierrelatte in April 1967.

From 1971-75, nuclear testing contributed to further development of SLBM warheads, as work began on the development, testing, and fabrication of a smaller tactical nuclear warhead. This tactical warhead, to be shared by the Army (for its Pluton missile), the Tactical Air Force (gravity bombs for the Jaguar A and Mirage IIIE aircraft), and the Naval Air Force (gravity bombs for the Super Etendard aircraft), was designated AN 51 and AN 52, and was tested in 1971.

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[19] Bertrand Goldschmidt, former head, Chemistry and International Relations Divisions, CEA, "The Origins of the French Nuclear Weapons Programs," a lecture at The Wilson Center, Smithsonian Institution Building, Washington, D.C., 12 June 1986.

Underground testing at Mururoa and Fangataufa

As early as 1972 President Georges Pompidou ordered the Army to find a suitable location for underground testing in the Pacific. Initially the Army considered Eiao, a small uninhabited island in the Marquesas group. Holes were drilled through the basalt to a depth of 1000 meters (m), but due to the fragility of the basalt, Eiao was found unsuitable. On 30 August 1973, Defense Minister Robert Galley announced that Fangataufa had been chosen, which also contained a basalt base.[20] On 8 June 1974 President Valery Giscard d'Estaing stated that, starting in 1975, France would only test nuclear weapons underground.[21] France conducted the first two "exploratory" underground explosions at Fangataufa in 1975. Every other test since 1975, however, with the exception of the last test in 1988, has been conducted at Mururoa. The tests were purportedly moved back to Mururoa to avoid the additional expenditures of operating two test sites.[22]

Underground tests at Mururoa have been conducted at the bottom of shafts drilled through both the outer rim of the atoll, and the lagoon, down to the basalt core of the atoll, to a depth of 500-1200 m, depending upon the yield of the device.[23] From 1976 through 1981, all were conducted in the outer rim of Mururoa atoll.[24]

By the early 1980s, the rim, which has been compared to swiss cheese by the workers at Mururoa, had been exhausted.[25] As a consequence, DIRCEN decided

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[20] Danielsson, *Poisoned Reign* (short title), pp. 196, 198.

[21] *Ibid.*, p. 204.

[22] DIRCEN, "Dossier no. 1," section 51.

[23] DIRCEN, "Dossier no. 1," section 51; French Government, "French Nuclear Testing in the South Pacific," *New Zealand Foreign Affairs Review*, V.32, January-March 1982, p. 21.

[24] The CEA only had a 25 kilometer (km) long stretch of land for the whole testing program, since by 1975 half of the 50 km circumference of the narrow rim was covered with roads, air strips, bunkers, and warehouses; Danielsson, *Poisoned Reign*, p. 245.

[25] Although there was a 25 km stretch of land, each shaft had to be separated by a distance of 400-1000 m (depending on the yield of the device), as a result

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in early 1979 to conduct tests in the "zone centrale" of the atoll, i.e. in shafts drilled in the central basalt core of the atoll, under the lagoon itself.[26] In order to validate the idea, the DIRCEN conducted two tests in the "zone centrale" in 1981,[27] starting with a test on 5 December 1981. The following year was marked by higher and higher yield tests in the center of the lagoon.[28] As the shafts are drilled in the lagoon, further from the outside wall of the atoll, they are not quite as deep, ranging between 500 and 700 m.[29] This new technique is said to increase the capacity of both the Mururoa and Fangataufa test sites.[30] Since October 1986, all tests have been conducted in the "zone centrale."[31]

Preparation for an underground test: The nuclear device is placed in a test canister, a white steel tube over 20 m long and 1 m in diameter. The canister contains diagnostic instruments capable of recording what happens during the explosion. When the shafts were located on dry land, the test canister was transported in a horizontal position on a 28-wheel trailer from the assembly plant to the shaft, usually only a few kilometers away. It was then raised to a

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[25](...continued)
of the expanse of rock that is fractured with each test. According to official estimates, a "high" yield test 900 m underground results in a 220 m fracture radius, a 50 m cavity radius, and a chimney height of 300 m; French Minister of Foreign Affairs/Minister of Defense, *Les Essais Nucléaires Français* (Brétigny-sur-Orge: S.ET.A.M.C.A., circa 1986), graph no. 6.

[26] DIRCEN, "Dossier no. 1," section 51. One source implied that the tests were moved to the lagoon so that the direct effects (such as surface fracturing, subsidence, venting) could no longer be observed; M.P. Hochstein and M.J. O'Sullivan, "Geothermal Systems Created by Underground Nuclear Testing: Implications for Long-Term, Direct Effects of Underground Testing," paper presented at the International Scientific Symposium on a Nuclear Test Ban, Las Vegas, Nevada, 15-16 January 1988, p. 7.

[27] CEA, *Rapport Annuel 1981* (Paris: CEA, 1982), p. 51.

[28] CEA, *Rapport Annuel 1982* (Paris: CEA, 1983), p. 71.

[29] Gaston Flosse, French State Secretary for the South Pacific, "Nuclear Tests," press conference in London, translated by the French Embassy Press and Information Service (London), 19 November 1987, p. 1.

[30] DIRCEN, "Dossier no. 1," section 1/11, p. 1.

[31] CEA, *Rapport Annuel 1986* (Paris: CEA, 1987), p. 20.

vertical position and lowered into the water-filled shaft with the help of cables. When the tube reached the bottom, the shaft was filled with a cement plug which encased the cables, and covered with a concrete lid.[32] For the lagoon tests, an offshore drilling platform (similar to those used for oil drilling), called Tila, now operates in the lagoon. It takes 4-6 weeks to drill a 700 m deep, 2 m diameter, testing shaft.[33]

Detonation of an underground test: The device is detonated from a blockhouse, or "PC de tir," which in the case of the HÉRO test of 24 October 1985, was located 20 km from test site.[34] Following the detonation, the ground first bulges and then falls back, leaving a depression (only visible in rim tests), and accompanied by a "light earthquake" and waves travelling across the lagoon waters.[35]

Following each underground detonation, radioactive samples are taken from the cavity to obtain a more accurate measure of the yield of the device.[36] For this purpose, a second shaft is drilled down at an oblique angle to the cavity. A new technique, called COSMOS (Colonne Oscillante Support de Mat de Forage "Off-Shore") was developed in 1983 to perform this drilling when tests are conducted under the lagoon.[37] In October 1986 a new barge entered service for both drilling shafts and post-test sampling use.[38]

In 1978, the total cost for each test amounted to about 35 million French francs, of which about 2 million francs was to drill the shaft. This was one-seventh of the cost of a test during the first year of underground tests, 1975, and

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[32] Agence France Presse (AFP) (Mururoa), dispatch dated 4 July 1978, cited in, Danielsson, *Poisoned Reign*, p. 248.

[33] Bertrand Labasse, "L'Enfer Maitrise," *TAM*, December 1985, pp. 22-25.

[34] Labasse, *op. cit.*, pp. 22-25.

[35] AFP (Mururoa), *op. cit.*, pp. 248, 251.

[36] DIRCEN, "Dossier no. 1," section 51.

[37] CEA, *Rapport Annuel 1983* (Paris: CEA, 1984), pp. 73-74.

[38] The entry into service of this barge at Mururoa lagoon has permitted all tests to be conducted in the "zone centrale"; CEA, *Rapport Annuel 1986* (Paris: CEA, 1987), p. 20.

only half of what an atmospheric test costs.[39] The transition from testing under the rim to under the lagoon reportedly involved a 30 percent increase in costs.[40]

Other activities at Mururoa

Since 1966 Mururoa has also been used to conduct safety tests and other activities related to the nuclear weapons program. The "safety firing area" is probably on the north coast of Mururoa. The only two known safety tests were GANYMÈDE on 21 July 1966, where an AN 22 bomb fragmented (dispersed plutonium, without any detonation) on the surface of Mururoa, and another in 1971.

It appears that, following the two "safety firings" of 1966 and 1971, and the resultant dispersal of plutonium, this land area was then used as a "safety trial area." According to technicians employed at Mururoa, the "thoroughly contaminated" north coast of Mururoa has, since 1971, been used for security exercises to train personnel in "the procedures to be followed in the event of an aircraft accident." To prevent the "several kilograms of plutonium" from blowing away, it was "fixed" in place with a layer of tar.[41]

Mururoa is also used for detonation experiments "for the study of shockwaves."[42] These experiments, which are carried out in concrete bunkers on the surface of the atoll, and result each time in the release of unknown quantities of plutonium, presumably involve the study of the implosion of the chemical high explosive which surrounds the fissile material (single-point safety tests). The bunkers are usually sealed and abandoned at the end of each experiment. However, in early July 1979 DIRCEN decided to decontaminate and

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[39] AFP (Mururoa), *op. cit.*, p. 248.

[40] Reuters, "France Plans to Continue A-Tests at Pacific Atoll," *Newark Star-Ledger*, 10 September 1985, p. 27.

[41] Statement issued by Conféderation Française Democratique du Travail Union (CFDT), the French trade union which represents technicians employed at Mururoa; CFDT Section B-III, "Contamination at Mururoa," Paris, 19 October 1981, and published by *Libération*, 6 November 1981. This facility is thought to be similar in purpose to the U.S. Interservice Nuclear Weapons School at Kirtland Air Force Base, New Mexico, where U.S. and British personnel conduct nuclear weapons accident response exercises using a Thorium 232 sludge spread over the ground.

[42] Stewart Firth, *Nuclear Playground* (Honolulu: South Sea Books, 1987), p. 103.

re-use the latest chamber built on the coral rim, for "economy reasons." Following the experiment of 6 July 1979, "decontaminators" entered the bunker, and caused a spark which ignited the acetone gas still filling the chamber. The blast killed two workers, injured four others, and spewed radioactive fallout over the atoll.[43]

Lastly, the land area of Mururoa has been used to store radioactive waste (including metal scrap, wood, resin plastic bags, and clothes) in a huge heap on the north coast of the atoll, eventually covering 30,000 square meters.[44]

Damage to the atolls

While these atolls were regarded by some as "ideal" for atmospheric tests (the nearest population center being over 800 km away),[45] it is now evident that it was a poor choice. Tests conducted under the rim and under the lagoon have caused severe damage to the atoll, and have reportedly contaminated the surrounding land and water.

Before 1981 the nuclear devices were detonated in shafts 500-1200 m directly below the rim of the atoll. The shallower the shaft, the closer the explosion was to the outer wall of the atoll, and the greater the possibility of causing damage to its foundation. Inevitably, multiple explosions have resulted in cracks, leakage, and seepage. There was an official admission in March 1988 by Admiral Thireaut that previous tests nearer the edges of the atoll may have contributed to underwater landslides of sections of coral limestone on the flanks of the atoll.[46]

French engineers claim that the underground tests are causing a slow but irreversible collapse of Mururoa atoll, about 2 cm per explosion, equalling 1.5 m

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[43] *Le Matin*, 8 August 1979, cited in, Danielsson, *Poisoned Reign*, p. 264.

[44] CFDT Section B-III, *op. cit.*

[45] According to DIRCEN, Mururoa was ideal for atmospheric testing because only 5000 inhabitants lived within a 1000 km radius of Mururoa, whereas an analogous computation for the Soviet Kazakstan and U.S. Nevada Test Site showed 4.195 and 37.5 million people, respectively; DIRCEN, "Dossier no. 1," section 3/41.

[46] Michael Richardson, "France to Shift Some Nuclear Tests to a 2d Site," *International Herald Tribune*, 28 March 1988.

from 1976 through 1981.[47] France has acknowledged that, following earlier explosions, there had been "minor subsidence of surface limestone immediately above test cavities."[48] As a result of the subsidence of the north and south zones of the atoll, the DIRCEN has had to heighten the roadway in these zones, since the end of 1978.[49]

Cracks have appeared on the outside wall of the atoll, below sea level, and are clearly shown on a French army map of June 1980.[50] It is reported that one such fissure, created by the nuclear blasts, is 50 cm wide by 800 m long, resulting in radioactive leakages to the ocean.[51] According to the French Government, the existence of peripheral fissures on the edges of the atoll "is in fact a natural phenomenon due to the subsidence of the sides of the massif under the weight of the coral which is covering it."[52]

It has been claimed that the explosions at Mururoa are regularly accompanied by venting, leakage and seepage, and that Mururoa is like a radioactive sponge, constantly contaminating the surrounding seas. Also, there was said to be a serious risk of contamination of the lagoon waters through seepage even when tests were conducted under the rim of the atoll. The consensus outside the French Government seems to be that this risk will surely increase now that tests are carried out in the center of the lagoon.

The French State Secretary for the South Pacific, Gaston Flosse, claimed that at the depth of the tests, around 700 m, "there is no leakage, no problem of

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[47] CFDT Section B-III, *op. cit.*; Reuters, *op. cit.*, p. 27, states the atoll has sunk 5 ft in places.

[48] Michael Richardson, "France to Shift Some Nuclear Tests to a 2d Site," *International Herald Tribune*, 28 March 1988.

[49] DIRCEN, "Dossier no. 1," section 2/21, pp. 1-2.

[50] This map was reproduced by *Pacific Islands Monthly*, August 1983, p. 35.

[51] *The Guardian*, September 1981, states that the crack is 15 to 19 inches wide and over half a mile long. Reuters, *op. cit.*, p. 27, puts the crack at 2,600 ft long and 1-2 ft wide.

[52] French Government, *op. cit.*, p. 21.

irradiation."[53] President François Mitterrand went even further by stating that the rate of radioactivity on Mururoa is lower than in Paris.[54]

The French nuclear test of 25 July 1979, as detected seismically at the Rarotonga station in the Cook Islands, appeared to be the largest earth tremor ever recorded from Mururoa. The blast appeared "strangely oversized" at 6.3 on the Richter scale, corresponding to a device with a yield in the 150-200 kt range.[55] What made this test different was that the device got stuck while being lowered down the 800 m shaft drilled in the southern portion of the coral rim. Unable to dislodge it, DIRCEN detonated it anyway, at a depth of only 400 m.

As a result an enormous chunk of the atoll's outer wall was blown out. A geologist at Victoria University, New Zealand, calculated that the initial blast created a cavity 140 m across and shattered a vast zone of rock above the cavity which collapsed.[56] Another source estimates that the chunk of the outer wall that was pried loose by this accident alone equalled one million cubic meters of coral and rock.[57] It fell about three hours later, producing a tidal wave which spread through the Tuamotus, injuring six people on the southern part of the atoll.[58]

According to the French authorities the tidal wave was of natural origin. The CEA denied any connection between the test and the tidal wave shortly thereafter, and denied that anything had gone wrong with the test. However, in

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53 Gaston Flosse, "Nuclear Tests," press conference in London, translated by the French Embassy Press and Information Service (London), 19 November 1987, p. 1.

54 François Mitterrand, press conference in Djakarta, Indonesia, translated by the French Embassy Press and Information Service (London), 17 September 1986, p. 1.

55 Danielsson, *Poisoned Reign*, p. 263.

56 Greenpeace, "French Nuclear Weapons Testing in the Pacific," press briefing on 4 September 1985, pp. 2-3.

57 According to Haroun Tazieff, the French Government Commissary for the Prevention of Natural Disasters, cited in, Jean Chesneaux, "France in the Pacific," *Peace Dossier 20* (Melbourne, Australia: Victorian Association for Peace Studies, February 1988), p. 8.

58 According to 1979 statement issued by the CFDT, cited in, Danielsson, *Poisoned Reign*, p. 263. The device was detonated on the south rim of Mururoa.

October 1985 the DIRCEN did acknowledge "the accident of 25 July 1979," although did not elaborate.[59] As a result of this accident, the maximum yield of tests was lowered temporarily, until the lagoon method of testing was mastered by late 1982, when the yields started to climb again.

Lastly, a number of devastating cyclones have hit Mururoa in the last decade, some of which have wrought havoc to the north coast. One of the most severe cyclones hit Mururoa on 11-12 March 1981, sweeping the radioactive garbage located on Mururoa's north rim into the lagoon (the atoll does not rise much above sea level).[60] In 1981 a French official confirmed the story by stating that "some of the nuclear waste left by the atmospheric explosions made before 1975, may have crossed the lagoon to the eastern side of the atoll."[61] Previously, nuclear waste had not officially existed at Mururoa. The plutonium-impregnated tar of the safety trial area was also torn off the land, and spread over the atoll.[62] Other cyclones which may have dispersed radioactive material in 1981 alone include those of 22 March 1981, 11-12 May 1981,[63] and 2 August 1981.

The DIRCEN has not appeared to have taken any steps to stop further dispersal of radioactive material due to cyclones. They have instead, since 1983, ensured that the cyclones not interrupt the testing schedule, by adjusting the schedule so that all the tests are now conducted outside of the cyclone period (December-April).[64]

In addition, protective walls were erected in 1981 and 1982 to protect the living area and industrial zone of Mururoa test site from the risk of cyclones. These walls face both the ocean (mean height of 4 m, total length of 4.5 km), and the lagoon (mean height of 2 m, total length of 3 km).[65]

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[59] DIRCEN, "Dossier no. 1," section 51.

[60] CFDT Section B-III, *op. cit.*

[61] *Pacific Islands Monthly*, October 1981, p. 23, cited in, Firth, *op. cit.*, p. 105.

[62] CFDT Section B-III, *op. cit.*

[63] French Government, *op. cit.*, p. 21; ..."some residues originating from overhead tests made before 1975 were dispersed by a storm on the night of 11-12 May 1981."

[64] DIRCEN, "Dossier no. 1," section 2/21, pp. 1-2.

[65] *Ibid.*

Scientific inspection teams

French authorities have made great efforts to discount criticism that underground tests are unsafe. Three investigative teams of international scientists -- the Tazieff mission of 1982, the Atkinson mission of 1983, and the Cousteau mission of 1987 -- have, according to French authorities, given Mururoa a clean bill of health. It should be emphasized that these missions were exceedingly short, were not allowed to visit the most contaminated areas, and relied almost exclusively on data provided by the French military. Independent analysis has proven more critical of the test program's safety.

The Tazieff mission was organized by Defense Minister Charles Hernu, and headed by Haroun Tazieff, the Government Commissary for the Prevention of Natural Disasters. The team was allowed to study geological and radiobiological aspects during their three day visit (26-28 June 1982). The team brought their own monitoring instruments to check for any venting that occurred during the nuclear test which they witnessed on 27 June 1982. However, as the yield of the device detonated on this occasion was "the smallest ever," less than 1 kt, little could be learned about the risks during the normal test program, when yields are substantially greater.[66] Following the dispersal of significant quantities of plutonium into the marine environment as a result of cyclones in 1981, the Tazieff mission was forbidden from visiting the north coast of Mururoa, where the nuclear waste dump had been located.

Growing concern by Pacific countries that testing at Mururoa might be less safe that officially claimed led to an invitation by France to interested Pacific countries to visit Mururoa. In what became known as the Atkinson mission, five scientists from Australia, New Zealand, and Papua New Guinea visited Mururoa for four days in October 1983. The inquiry was conducted under strict French supervision, which dictated not only the terms of reference, but also the points on the atoll to be visited and the type and location of sampling allowed. Thus the team did not observe any tests; were not allowed to inspect any test sites; were forbidden from visiting the radioactive dump on the north coast, including the "safety trial area";[67] and were not allowed to collect bioter or sediments from the lagoon for testing. Their measurements were restricted to soil testing near living quarters; for assessment of underground effects, selected data provided by

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[66] Danielsson, *Poisoned Reign*, pp. 294, 296.

[67] *Ibid.*, p. 317.

the French authorities had to be used.[68] Furthermore, the Atkinson mission lacked personnel qualified in either medicine or geo-thermal fluid mechanics.

The most recent mission to visit Mururoa was led by marine explorer Jacques-Yves Cousteau in June 1987. For five days Cousteau and his crew aboard the Calypso were allowed restricted access to Mururoa atoll. In a November 1988 press conference, Cousteau presented a number of preliminary scientific findings; foremost that analysis of samples of sediments, water and plankton from Mururoa did not reveal significant amounts of radioactive contamination, with the exception of radioactive iodine. However, once again this mission was not allowed access to those areas thought to be most contaminated with radioactive waste. Cousteau produced an underwater film showing large fissures in the submerged portion of the atoll, clearly a result of the underground testing program.[69] Another film sequence showed the venting of a 60 m geyser of water during a nuclear test.

A number of questions about the state of Mururoa still remain unanswered. A long-term, independent, and thorough examination of the environmental impact of France's testing program is needed. In February 1989 the European Parliament narrowly rejected a resolution calling for the establishment of an independent, international commission of scientists (to include personnel qualified in medicine, biology, and geo-thermal fluid mechanics) to travel to French Polynesia and investigate the effects of French nuclear tests on human health and the environment. However, during the debate the European Commission indicated that it was considering approaching the French government to discuss the commission's concerns about this issue.

Future underground test sites

France has acknowledged that it cannot continue to test all of its nuclear weapons underground at Mururoa because of the damage to the atoll. The government is therefore once again looking to establish a new center for the underground testing of nuclear weapons. Several locations have been considered, the most likely candidate being the nearby Fangataufa atoll (especially following

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[68] Hochstein and O'Sullivan, *op. cit.*, pp. 7-8.

[69] Unfortunately the Cousteau film crew did not investigate below about 50 m in depth. Filming down to a depth of 700 m or more (minimum depth for underground tests) would have revealed the true geological state of the basalt base of the atoll. The discovery of fissures at that depth would imply that radioactivity from the underground test cavities has reached the ocean.

the test of 30 November 1988). Other options are thought to include the Kerguelen Island in the southern Indian Ocean,[70] mainland France,[71] and the U.S. NTS,[72] although all are unlikely prospects.

In March 1988, Vice Admiral Pierre Thireaut, the Commander-in-Chief of the French Navy in the Pacific,[73] revealed that, in order to prevent serious fractures in the rock of Mururoa that might be caused by repeated underground explosions (thus potentially leading to leakage of radioactive material), the most powerful blasts[74] in the test program will in the future be conducted on Fangataufa. Fangataufa atoll, at 5 km by 8 km, only a fraction of the size of Mururoa (see Appendix 1), has been the location for five atmospheric and three underground French nuclear tests, including the largest device ever tested by France (2.6 Mt).[75] It is unclear how this atoll could withstand many new tests,

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[70] Although once an option, use of the French-owned Kerguelens was ruled out by Defense Minister Charles Hernu on 28 December 1984. France presently maintains a scientific and meteorological station at Kerguelen, an archipelago in the southern Indian Ocean comprised of some 300 islands. Drawbacks include a hostile climate, and difficult access by air and sea.

[71] The prospect of testing nuclear weapons in France itself is low indeed. Nevertheless, the Australian Bureau of Mineral Resources has identified two sites in France suitable for underground nuclear testing: Gueret and Mageride in the Massif Central, and other sites in Corsica; Jane Ford, "French Told: Take Your A-tests Home," *New Scientist*, 15 November 1984, p. 8.

[72] According to one source, the U.S. secretly offered France the use of its nuclear testing facilities at the NTS. Although the French government denied that any such offer had been made, it is said that France rejected the offer "for reasons of national pride" and because it would "compromise development of an independent French nuclear deterrent." The offer remains open. The U.S. motive for such an offer would be to temper the anti-nuclear feeling in the Pacific which the French test program generates; Michael Richardson, "U.S. Offered Nevada Site For French Nuclear Tests," *International Herald Tribune*, 22 June 1987, p. 1.

[73] Vice Admiral Pierre Thireaut is also Commander of the Pacific Test Center (COMCEP).

[74] It is said that Mururoa atoll can no longer support tests of 100 kt; Reuters, *op. cit.*, p. 27.

[75] *The Guardian* of September 1981 reported that as a result of these tests the atoll of Fangataufa "has been literally blasted out of the sea."

particularly those of higher yield, when Mururoa did not. Admiral Thireaut emphasized that the impending move to Fangataufa was a precautionary measure, and asserted that there was "absolutely no problem of pollution of Mururoa. It is zero."[76] Yet, a week after the disclosure by Admiral Thireaut, the French Embassy in Wellington said Paris believed that Admiral Thireaut had been misquoted as confirming a shift of testing from Mururoa to Fangataufa. The Embassy statement said no decision had been made to expand or to transfer testing installations in the Pacific and that both atolls have always been used in the program.[77] A nuclear device was detonated at Fangataufa on 30 November 1988, the first detonation recorded from this site since 1975.

Types of tests

All of France's nuclear tests since 1960 have been weapons related, although a number of these tests were simultaneously studied for weapons effects, and the possible application of peaceful nuclear explosions.

Weapons related: General Mermet, Director of DIRCEN, stated in October 1985 that around 20 tests are required for each type of nuclear weapon in the French arsenal.[78] With 172 French tests this would mean about eight warhead types have been developed and deployed (some tests have no doubt been conducted for designs that were never deployed). The most likely candidates are:

1) AN 11 and AN 22:	60-70 kt pure Pu-239 fission (Mirage IVA aircraft, IOC 1964);
2) MR 31:	120 kt pure Pu-239 fission (S2 IRBM, IOC 1971);
3) MR 41:	500 kt boosted fission using U-235 (M1 and M2 SLBM, IOC 1971);
4) AN 51 and AN 52:	15/25 kt Pu-239 fission (Pluton/Jaguar A/Mirage IIIE/Super Etendard, IOC 1972);
5) TN 60 and TN 61:	1 Mt thermonuclear (M20 SLBM and S3D IRBM, IOC 1976);
6) TN 70 and TN 71:	150 kt thermonuclear (M4A and M4B SLBM, IOC 1985);
7) TN 80 and TN 81:	300 kt thermonuclear (ASMP missile, IOC 1986);
8) ERW:	Enhanced Radiation Warhead (Hadès missile, IOC 1992).

(IOC: Initial Operational Capability)

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[76] Michael Richardson, "France to Shift Some Nuclear Tests to a 2d Site," *International Herald Tribune*, 28 March 1988.

[77] Jane Clifton, "France Denies Shift of Test Site," *Dominion*, 6 April 1988; Paul Hewlett, "Atoll Plan Confusion," *Star*, 7 April 1988.

[78] See quote from General Mermet; Jacques Isnard, "L'enjeu de l'Indépendance Nationale," *Le Monde*, 25 October 1985, p. 32; Labasse, *op. cit.*, p. 25.

The recent introduction of higher power U.S. Cray super-computers to the nuclear weapons design lab at the Centre d'Études de Limeil-Valenton will no doubt reduce the number of tests necessary to design each future French warhead.[79] Comparable U.S. utilization of Cray-1 and -2 computers for simulation and modelling of nuclear weapons has reduced the number of U.S. tests per warhead type to around six.[80]

A large number of tests are required to develop prototypes for France's various warhead designs. The first thermonuclear test of 24 August 1968, for example, involved an experimental device that had a yield of 2.6 Mt and weighed an estimated 3000 kg.[81] Eight years later (1976), France deployed the first thermonuclear warhead, the 1 Mt TN 60 warhead for the single warhead M20 SLBM. In 1977, the CEA began replacing these warheads with a lighter version, the TN 61. Today, the whole reentry vehicle for the M20 SLBM weighs only about 700 kg (1543 lbs).

While certain tests are to develop prototypes, over half of all tests are to refine and modify proven designs. The French regularly develop and deploy lighter versions of existing warheads, while maintaining the yield. The HÉRO test of 24 October 1985, for example, was part of an effort to reduce the weight of an existing tactical warhead. Also, one of the major differences between the 150 kt TN 71 warhead, and the TN 70 which it replaced, was a reduction in weight of 25 kg.[82]

Weapons effects tests: France's involvement with studying the effects of nuclear weapons began in 1957, three years before France's first test. In 1957 a French delegation travelled to the U.S. NTS for an orientation in nuclear test effects. These visits included participation in the U.S. atmospheric nuclear test SMOKY

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[79] Limeil-Valenton now has four U.S.-supplied supercomputers: two Control Data Cyber 860s; one Cray 1S; and one Cray X/MP 416, operational since June 1987. The X/MP is at least five times as powerful as the three older computers combined, and more powerful than a Cray 2 "in the problems specific to Limeil-Valenton"; CEA, *Rapport Annuel 1987* (Paris: CEA, 1988), p. 19.

[80] Robert S. Norris, Thomas B. Cochran, and William M. Arkin, Nuclear Weapons Databook Working Paper 86-2 (Rev. 2C), *Known U.S. Nuclear Tests July 1945 to 31 December 1988*, January 1989, p. 14.

[81] AFP (Papeete), "Conference de Presse du Directeur des Centres d'Expérimentations Nucléaires Françaises," 28 August 1968.

[82] Labasse, *op. cit.*, p. 22-25.

on 31 August 1957, in which the French tested a selection of their underground personnel shelters, equipment, and instrumentation. The Service Nationale de la Protection Civile (SNPC) of France was invited to take part in test SMOKY (part of Operation Plumbob), in response to a request from the French Government.[83] These were the first nuclear effects experiments ever made by the U.S. for a foreign nation.[84]

France engaged Ammann & Whitney, consulting engineers, as their American representatives for the construction of shelters in the Yucca Flats area at the NTS.[85] The French designs included two reinforced concrete underground personnel shelters, and three underground structures for testing entranceways. They were designed to resist over-pressures of approximately 130 psi.[86] Mice were used for biological tests in all five shelters to determine the environmental aspects of the structures when subjected to nuclear blast.[87]

Only unclassified information on the results of the test was to be provided to the French delegations, and thus the yield of shot SMOKY was declassified (43 kt). French officials and technicians visited NTS during 3-9 December 1957 and 18-21 February 1958 for further orientation in nuclear test effects and to inspect the shelters tested during the summer 1957 test series.[88]

The French atmospheric tests of the 1960s were studied for their weapons effects, especially the first three Algerian tests of 1960-61 (see Table 1). Likewise the atmospheric tests at the Pacific Test Center between 1966 and 1974 were probably also used as effects tests.

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[83] U.S. AEC Civil Effects Test Group, *Operation Plumbob, Project 30.6: Test of French Underground Personnel Shelters*, 19 June 1962, p. 6.

[84] West Germany also tested shelters in Operation Plumbob.

[85] Office of Test Information, Nevada Test Organization, press release OTI-57-18, dated 1 June 1957, p. 1.

[86] *Ibid.*, press release OTI-57-94, dated 26 August 1957, p. 1.

[87] U.S. AEC Civil Effects Test Group, *Operation Plumbob, Project 30.6: Test of French Underground Personnel Shelters*, 19 June 1962, p. 5.

[88] U.S. AEC, "Visit of French and German Officials and Technicians to Nevada Test Site," memorandum dated 29 November 1957; U.S. AEC, press release LAV-58-17 dated 17 February 1958, both released under the FOIA.

Since the testing program moved underground in 1975, France is not known to have conducted any underground effects tests. By comparison, the U.S. has conducted 59 underground effects tests since its last atmospheric test on November 4, 1962, or roughly 9.3 percent of their total number (634) of tests since that date.[89]

Weapons effects simulation: Since France moved her testing program underground in 1975, nuclear weapons effects have had to be simulated in the laboratory. A large number of government and contractor facilities have been established to conduct effects research.

For the purpose of simulating the thermal and blast signatures of nuclear weapons, the Central Technical Establishment for Armament (ETCA) operates two research and development (R&D) centers at Gramat (Lot) and Bouchet (Essone).[90] The Gramat Research Center (CEG) covers an area of 250 hectares, including a large-scale nuclear blast simulator for work on the hardening of weapon systems (tanks, aircraft, etc.) and military facilities against nuclear blast effects.

The Bouchet Research Center (CEB) has 10,000 square meters of laboratories at Arcueil (Val-de-Marne) devoted to the study of nuclear defense, protection and hardening. The Odeillo Center (Pyrénées-Orientales), an annex of the CEB, is devoted to research on protection (of humans and weapons) against thermal radiation from nuclear explosions, and is equipped with two solar furnaces for the purpose.

Since 1980 the U.S. Army Ballistics Research Laboratory has provided France with simulation technology pertaining to thermal and blast signatures of nuclear weapons, to help France in its development of these facilities for nuclear weapons effects research, which include the verification of the nuclear hardness

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[89] Most of these U.S. effects tests were conducted in underground, horizontal tunnels, some 1000 ft long. Very occasionally a vertical shaft is used; Thomas B. Cochran, William M. Arkin, Robert S. Norris, Milton M. Hoenig, *Nuclear Weapons Databook, Volume II: U.S. Nuclear Warhead Production* (Cambridge, Massachusetts: Ballinger Publishing Company, 1987), pp. 46, 55.

[90] Centre d'Etudes du Bouchet, *Le Centre d'Etudes du Bouchet*, no date, not paginated; Établissement Technique Central de l'Armement, *Établissement Technique Central de l'Armement*, no date, not paginated.

of military equipment.[91] In turn, U.S. technicians now regularly travel to France to use French nuclear blast simulation facilities.[92]

For the purpose of simulating the biological effects of initial nuclear radiation upon humans, and thus the protection of military personnel against radiation, the CEB uses neutron, gamma, and x-ray sources to simulate radiation from nuclear weapons. Similar research is conducted by the Animal Biology Research Group at Fontenay-aux-Roses (Hauts-de-Seine), in a laboratory operated jointly by CEB and the CEA. An additional chamber is used for simulating radioactive fallout, based on particle size.

Research into vulnerability and hardening (of weapon systems and installations) to nuclear electromagnetic pulse (EMP) is conducted in numerous French government and contractor R&D establishments. The CEB and CEG each have two EMP simulators (the Siem I/Siva, and the Gedeon/Cythare, respectively). The Direction des Engins installed "Esope" and "Siem II" EMP simulators at the Landes Test Center (CEL) in 1978 for testing of complete missiles prior to flight testing.[93] The Military Applications Branch of CEA operates a R&D facility called CEA-CESTA, located at Le Barp (Gironde), responsible for the "militarization" of French nuclear warheads, including simulated nuclear EMP and blast.

EMP simulation is also conducted by the Space and Ballistic Systems Division of Aerospatiale, the prime contractor for all of France's ballistic missiles. The Les Mureaux (Yvelines) facility received its first EMP simulator in 1973, called the "Mule." The latest facility, a 16.50 m high building constructed entirely of nonmetallic materials, houses the "Super Pégase" EMP antenna.[94] Aerospatiale's facilities at Cannes (Alpes-Maritimes) and Aquitaine (Gironde) also host EMP simulators for use on individual missile components. In addition, Aerospatiale

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91 U.S. Army Armament R&D Center, *Laboratory Posture Report FY 1983*, report no. RCS-DRCLD-101, pp. 1-15.

92 Interview with officials from the Office for International Cooperative Programs, HQ, U.S. Army Materiel Command, November 1988.

93 Shirley Compard, "La Parade Existe," *Aerospatiale Revue*, no. 7, March 1984, p. 6.

94 "News Briefs," *Aerospatiale Revue*, no. 11, July/August 1984, p. 2.

and Thomson-CSF have developed mobile EMP simulators for use on S3D IRBMs in their silos.[95]

Peaceful nuclear explosion experiments: From 1961 to 1966 the French detonated 13 underground nuclear explosions in the Taourirt Tan Afella granite intrusive (also called Hoggar Massif) in what was then French Algeria. Though military tests, they were also experiments in the peaceful use of nuclear explosions, as part of the CEA Applications des Explosions (APEX) program. The French were primarily interested in gas storage and hydrocarbon stimulation. The French reported on some of the results of this study at the 1970 American Nuclear Society meeting in Las Vegas, and in the IAEA meetings in Vienna in 1970 and in Geneva in 1971. Furthermore, on 26-29 October 1971, there was the French-American (CEA-USAEC/Lawrence Livermore Labs) technical exchange of geologic information (and the exchange of rock samples from the respective sites) related to the peaceful uses of nuclear explosives, held at Berkeley, California.[96]

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[95] Shirley Compard, "La Parade Existe," *Aerospatiale Revue*, no. 7, March 1984, pp. 6-7.

[96] Stephens, *French-American*, 1972.

TABLE 1:

KNOWN FRENCH NUCLEAR TESTS, 13 FEBRUARY 1960-31 DECEMBER 1988

A) ATMOSPHERIC/ALGERIA:

Overview: The first generation of French nuclear arms, the AN 11 fission bombs carried by the Mirage IVA aircraft, were derived from the devices used in the four atmospheric explosions in 1960 and 1961. All four atmospheric tests were conducted at the Reggane Proving Grounds, in what was then French Algeria. Sources for data on atmospheric tests in Algeria, 1960-61.[1]

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
1. 02-13-60	GERBOISE BLEUE	07:04:00.0	0:04 W 26:19 N	tower/344 ft[2]	WE	60-70 kt[3]

Primarily a weapons effects test to assess the survivability of French military systems and personnel in a nuclear environment. Military equipment exposed to the test (at varying distances from ground zero) included superstructures of warships (to discover if a nuclear blast could capsize a ship), aircraft, tanks, buildings, shelters, combat helmets, etc. In addition, the Health Service conducted biological experiments designed to test radiation measurement devices (dosimeters). Animals (guinea pigs, fish, birds) were exposed to the test,[4] as were 150 Algerian prisoners.[5] Following the test a pilot-less aircraft measured the radioactivity in the interior of the atomic cloud, while measurements close to the ground were aided by helicopters.

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
2. 04-01-60	GERBOISE BLANCHE	06:17:00.0[6]	0:09 W 26:06 N	platform/ surface	WR	<20 kt[7]

The Ministère des armées declared that the detonation of this device (weighing 2,840 lb[8]) will mark a new stage in the miniaturization of the warheads,[9] and an important step toward the creation of an operational device.[10]

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
3. 12-27-60	GERBOISE ROUGE	07:30:00.0	Hammoudia	tower/100 m	WE	several kt[11]

Like the first test, military materiel (aircraft, radars, etc.) and animals (mice and goats) were placed at varying distances from ground zero.[12] This test was "essentially an experiment in physics, designed to study the phenomena involved in a nuclear explosion, as well as the effects of atomic radiation and the measures against irradiation."[13]

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
4. 04-25-61	?	06:00:00.0	Reggane	tower	?	<1 kt[14]

Hastily and prematurely detonated to avoid possible seizure as a result of the rebellion which began on 22 April 1961 (rebellion initiated by General Maurice Challe, former Commander-in-Chief of French forces in Algeria, and became known as "The Revolt of the Generals"). Outside observers often described the test as a failure, a "fizzle", or an accident,[15] when in fact the explosive was probably detonated as fast as possible (thus getting rid of fissile material on hand), rather than the detonation being "optimized" to provide a high yield.[16]

B) UNDERGROUND/ALGERIA:

Overview: The thirteen underground test concerned the miniaturization of the bomb to be carried by the Mirage IVA aircraft. All 13 tests were conducted at In Ecker, in the southern part of what was then French Algeria. Although primarily military experiments, some tests were also studied for their application of peaceful uses as part of the CEA Applications des explosions (APEX) program.[17] Sources for data on underground tests, 1961-66.[18]

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
5. 11-07-61	AGATE	11:29:59.931	5:03:07.6 E 24:03:25.5 N	shaft?[19]	WR	<20 kt; "weak"
	France's first underground nuclear test.					
6. 05-01-62	BÉRYL	10:00:00.458	5:02:30.8 E 24:03:46.8 N	shaft?	AN 11	>20 kt; "middle"
	Test of the prototype for the first generation of French atomic weapons, the AN 11 bomb for the Mirage IVA aircraft.[20] An accidental release of radioactive gases resulted in the contamination of twelve soldiers.[21]					
7. 03-18-63	ÉMERAUDE	10:02:00.351	5:03:07.9 E 24:02:28.9 N	shaft?	WR	4.86 m_b (10 kt)[22]
8. 03-30-63	AMÉTHYSTE	09:59:00.328	5:03:25.2 E 24:02:36.0 N	shaft?	WR	<20 kt; "weak"
9. 10-20-63	RUBIS	13:00:00.011	5:02:19.0 E 24:02:07.8 N	shaft?	WR	5.49 m_b (68 kt) 52 kt[23]
	The second largest yield of the 13 underground tests in Algeria.[24]					
10. 02-14-64	OPALE/MICHELE?	11:00:00.347	5:03:08.6 E 24:03:13.1 N	shaft/-353 m	WR/APEX	4.52 m_b (3.7 kt)[25]
	Thought to be part of the CEA APEX series.[26]					
11. 06-15-64	TOPAZE	13:40:00.367	5:02:04.4 E 24:03:59.8 N	shaft?	WR	<20 kt; "weak"
12. 11-28-64	TURQUOIS	10:30:00.035	5:02:30.1 E 24:02:30.7 N	shaft?	WR	<20 kt; "weak"
13. 02-27-65	SAPHIR/MONIQUE	11:30:00.039	5:01:52.3 E 24:03:31.4 N	shaft/-785 m	WR/APEX	5.70 m_b (127 kt) 117 kt[27]
	Largest underground explosion in Algeria,[28] and also part of CEA APEX series.[29]					
14. 05-30-65	JADE	11:00:00.037	5:03:03.1 E 24:03:18.0 N	shaft?	WR	<20 kt; "weak"
15. 10-01-65	CORINDON	10:00:00.043	5:02:02.6 E 24:03:53.7 N	shaft?	WR	<20 kt; "weak"
16. 12-01-65	TOURMALINE	10:30:00.088	5:02:48.9 E 24:02:37.4 N	shaft?	WR	4.86 m_b (10 kt)[30]
17. 02-16-66	GRENAT/GEORGETTE?	11:00:00.035	5:02:28.4 E 24:02:39.0 N	shaft/-403 m	WR/APEX	4.94 m_b (13 kt)[31]
	Thought to be part of the CEA APEX series.[32]					

C) **ATMOSPHERIC/PACIFIC**:

Overview: Starting with the atmospheric tests in the Pacific in 1966, the tests were divided up into "campaigns", with one campaign a year, each with specific objectives. Tests at CEP were conducted over the Mururoa and Fangataufa atolls, and over open ocean areas.[33] There are two frequently used sources for data on atmospheric tests, 1966-1974.[34]

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield

-------------------------------- First campaign (1966)[35] --------------------------------

The five tests and one "safety firing" of the 1966 campaign focused not only on fission devices for gravity bombs, but also, for the first time, testing of devices for the 2nd and 3rd legs of the "force de frappe"; the IRBM (fission) and SLBM (boosted fission) respectively.

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
18. 07-02-66	ALDÉBARAN	15:34:00.0	Mururoa	barge	AN 52	30 kt[36]

An experimental pure plutonium fission device with a yield in the tactical weapons range. ALDÉBARAN was detonated only on the third attempt.[37]

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
19. 07-19-66	TAMOURÉ	15:05:00.0	Fangataufa[38]	Mirage IVA Air-drop/parachute[40]	AN 11	about 60 kt[39]

An operational pure plutonium fission bomb dropped by, and similar to those found on, the Mirage IVA aircraft. TAMOURÉ was France's first airdrop of a nuclear device/weapon.

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
20. 07-21-66	GANYMÈDE	12:00	Mururoa	surface	SE (AN 22)	no detonation

A "safety firing" was conducted with success (no nuclear reaction) at Mururoa. This test was designed to check the security/locking apparatus[41] for the AN 11 bomb used in the previous test (19 July 1966).[42] Although the untriggered AN 11 bomb did not explode, it fragmented (the case broke apart), resulting in the dispersal of plutonium.[43] In order to contain the radiation, the contaminated area was covered over with bitumen.

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
21. 09-11-66	BETELGEUSE	17:30:00.0	Mururoa	balloon/600 m	MR 31	120 kt[44]

This experimental pure plutonium fission device was a prototype of the nuclear warhead for the future S2 IRBM.[45] The large refrigerator-sized iron box that contained the nuclear device hung from a helium-filled balloon.[46] French President de Gaulle attended this test, the highest yield atmospheric explosion to date. It is said that due to de Gaulle's impatience, the device was detonated despite adverse wind conditions, thus sending radioactive fallout to all islands west of Mururoa, including Western Samoa (2000 miles away), Fiji and Cook Islands.[47]

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
22. 09-24-66	RIGEL	17:00:00.0	Fangataufa	barge/ few meters	WR	150 kt

An experimental boosted fission device ("dopée") which used, for the first time, both plutonium and small quantities of thermonuclear material, thought to be tritium and/or deuterium gases.[48]

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
23. 10-04-66	SIRIUS	21:00:00.0	Mururoa	barge/ few meters	WR	300 kt

An experimental boosted fission device, using a different proportion of plutonium and thermonuclear material, resulting in an increased yield of 300 kt.

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield

---------------------------------- **Second campaign (1967)** ----------------------------------

Three low yield tests in 1967, involving research on the use of highly-enriched uranium 235 (U-235) as a fissile material in nuclear weapons (following the production of the first highly-enriched U-235 from the gaseous diffusion uranium enrichment facility at Pierrelatte in April 1967). These three tests probably looked at the use of U-235 as a fission primary for thermonuclear weapons.[49]

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
24. 06-05-67	ALTAÏR	19:00:00.0	Mururoa	balloon	WR	"small"
25. 06-27-67	ANTARÈS	19:30:00.0	Mururoa	balloon	WR	"small"
26. 07-02-67	ARCTURUS	17:30:00.0	Mururoa	balloon/sea level	WR	"small"

Although the first two devices were detonated under balloons, the third exploded at sea level due to a technical mishap, leading to severe fallout downwind.[50]

---------------------------------- **Third campaign (1968)** ----------------------------------

The purpose of the five tests in the 1968 campaign was to test prototype MR 41 warheads and the first thermonuclear devices.[51]

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
27. 07-07-68	?	22:00:00.0	Mururoa	balloon	WR	"small"

The first test of an experimental nuclear device using highly enriched U-235 (instead of plutonium).[52]

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
28. 07-15-68	?	19:00:00.0	Mururoa	balloon	MR 41	450-500 kt

First test of an operational boosted fission warhead using highly-enriched U-235 (boosted by the introduction of tritium).[53]

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
29. 08-03-68	?	21:00:00.0	Mururoa	balloon	MR 41	some 500 kt

The first test firing of the prototype MR 41 boosted fission warhead for the M1 SLBM.[54]

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
30. 08-24-68	CANOPUS	18:30:00.0	Fangataufa	balloon/600 m	WR	2.6 Mt[55]

France's first true thermonuclear explosion, using a highly enriched U-235 primary and a lithium-6 deuteride (deutériure de lithium) secondary.[56] The device weighed an estimated three tonnes.[57] After this blast, Fangataufa was said to be so heavily contaminated that it was declared off-limits for humans for the next six years. The next H-bomb in the 1968 series was thus detonated at Mururoa.[58]

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
31. 09-08-68	PROCYON	19:00:00.0	Mururoa	balloon/600 m	WR	1.2 Mt[59]

France's second thermonuclear explosion. Following PROCYON, no tests were conducted at Mururoa or Fangataufa for over a year, some say because of the serious radioactive contamination of these two sites.[60]

---------------------------------- **(1969)** ----------------------------------

A new series of tests concerning the miniaturization of future thermonuclear warheads was planned for 1969,[61] but was cancelled due to "budgetary reasons."[62]

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield

------------------------------- Fourth campaign (1970) -------------------------------

The purpose of the eight tests of the 1970 campaign: to verify a series of devices, mechanisms and phenomena associated with fission and fusion chain reactions (rather than in attaining high yields, e.g. 2.6 Mt in 1968), and on the optimal conditions for a fusion reaction.[63] Three of the tests were concerned with thermonuclear warheads, while the rest looked at diverse configurations of a fission primary.[64]

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
32. 05-15-70	ANDROMÈDE	18:00:00.0	Mururoa	balloon	WR	"intermediate"
33. 05-22-70	CASSIOPÉE	18:30	Mururoa	balloon	TN 60[65]	"intermediate"
34. 05-30-70	DRAGON	17:59:58.5	138.800 W (F) 22.200 S	balloon	WR	4.7 m_b "megaton range"
35. 06-24-70	ERIDAN	18:30:00.0	Mururoa	balloon	WR	"low"
36. 07-03-70	LICORNE	18:29:59.1	139.200 W (M) 21.800 S	balloon/60 m	TN 60	4.0 m_b; ≈ 1 Mt[66]

France's third thermonuclear test.[67] Six hours after the detonation, the officials returned to Mururoa, and Defense Minister Michel Debré swam in the lagoon to placate the critics.[68]

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
37. 07-27-70	PEGASE	19:00:00.0	Mururoa	balloon	WR	"low"
38. 08-02-70	ORION	19:00:00.0	Fangataufa	balloon	WR	"low intermediate"
39. 08-06-70	TOUCAN	19:00:00.0	Mururoa	balloon	WR	"intermediate"

------------------------------- Fifth campaign (1971)[69] -------------------------------

The purposes of the five tests and one "safety firing" of the 1971 campaign were three-fold: firstly to test and deploy the 500 kt MR 41 boosted fission warhead for the M1 and M2 SLBM (operational in late 1971);[70] secondly, to test the definitive formula for the 1 Mt TN 60 thermonuclear warhead intended for the M20 SLBM in 1976,[71] including work on "hardening", "miniaturizing", and the solving of all security problems.[72] Thirdly, to test a "tactical" warhead of yield between 10 and 25kt,[73] presumably for the Pluton missile.[74]

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
40. 06-05-71	DIONE	19:15:00.0	Mururoa	Atmospheric	AN 51	15 kt; "low"
41. 06-12-71	ENCELADE	19:15:00.0	Mururoa	Atmospheric	MR 41	450-500 kt

Following this test of a boosted fission MR 41 warhead, fallout fell over the atoll of Tureia on the night of 12 and 13 June 1971.[75]

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
42. 07-04-71	JAPET	21:30:00.0	Mururoa	Atmospheric	TN 60[76]	"low"
43. 08-08-71	PHOEBE	18:30:00.0	Mururoa	Atmospheric	TN 60[77]	"low"
44. 08-14-71	RHEA	18:59:59.2	139.000 W (M) 21.900 S	balloon/500 m	TN 60	4.7 m_b; 1 Mt[78] "high"

Fourth thermonuclear test since 24 August 1968.

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
45. ??-??-71	?	?	Mururoa	surface	SE (TN 60?)	no detonation?[79]

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield

------------------------------ **Sixth campaign (1972)** ------------------------------

The purpose of the three low yield tests of the 1972 campaign was to test the fission primary for the TN 60 thermonuclear warhead (operational in 1976).[80]

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
46. 06-25-72	?	?	Mururoa	Atmospheric	TN 60	low power
47. 06-30-72	?	?	Mururoa	Atmospheric	TN 60	low power
48. 07-29-72	?	?	Mururoa	Atmospheric	TN 60	low power

------------------------------ **Seventh campaign (1973)** ------------------------------

The purpose of the five low yield tests in the 1973 campaign was, principally, to work on the miniaturization and the "militarization" of the TN 60 thermonuclear warhead (its resistance against blast and other effects of ABM missiles).[81]

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
49. 07-21-73	?	18:00:00.0	Mururoa	Atmospheric	TN 60[82]	about 5 kt
50. 07-28-73	?	23:03:00.0	Mururoa	Atmospheric	TN 60?	"small"
51. 08-19-73	?	?	Mururoa	Atmospheric	TN 60?	5-10 kt
52. 08-25-73	?	?	Mururoa	Atmospheric	TN 60?	?
53. 08-28-73	?	?	Mururoa	Mirage IIIE Airdrop	AN 52	6.6 kt[83]

------------------------------ **Eighth campaign (1974)** ------------------------------

The purpose of the eight tests in the 1974 campaign included: conducting an airdrop from a Jaguar A aircraft, tests of small tactical A-bombs, and testing (for the first time) some experimental MIRV devices and prototypes.[84]

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
54. 06-16-74	?	?	Mururoa	balloon	TN 70?[85]	about 20 kt[86] 5 kt[87]
55. 07-07-74	?	?	Mururoa	balloon	TN 70?[88]	150 kt
56. 07-17-74	?	?	Mururoa	Atmospheric	TN 80?[89]	?
57. 07-26-74	?	?	Mururoa	Jaguar A Airdrop	AN 52	no yield?[90]
58. 07-29-74[91]	?	?	Mururoa	Atmospheric	WR	very high power[92]
	Probably the 5th thermonuclear test.					
59. 08-15-74	?	?	Mururoa	Atmospheric	WR	?
60. 08-25-74	?	?	Mururoa	Atmospheric	WR	?
61. 09-15-74	?	?	Mururoa	Atmospheric	TN 60?	1000 kt
	The last French atmospheric test.					

D) UNDERGROUND/PACIFIC:

Overview: All of the underground tests in the Pacific region were conducted at Mururoa, with the exception of the first two tests in 1975, and the last test of 1988, which were conducted at Fangataufa. Sources for data on underground tests, 1975-1988.[93]

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
(1975)						
Two "exploratory" underground tests during 1975, both at Fangataufa.						
62. 06-05-75	ACHILLE	18:15:00.0	Fangataufa[94]	shaft/-623 m[95]	?	5.3 m_b (20 kt) 4.8 m_b; 8 kt[96]
	The first underground test in the Pacific region, at Fangataufa.					
63. 11-26-75	HECTOR	00:48:00.0	Fangataufa[97]	shaft/-585 m[98]	?	5.2 m_b (15 kt) 4.9 m_b
(1976)						
Four tests during 1976, all at Mururoa.[99] On 28 February 1976, the Commander of the CEP officially closed the Fangataufa test site.						
64. 04-03-76	PATROCLE	00:45:00.0	Mururoa	shaft/-600 m	WR[100]	?
65. 07-11-76	?	00:29:59.05	138.768 W 21.859 S	shaft	WR	5.00 m_b 5.1 m_b (10 kt)
	This test resulted in radioactive gas which "did not escape along the predicted path, and the technicians are still trying to figure out what happened to it," according to Le Journal de Tahiti of 27 December 1976.[101]					
66. 07-23-76	?	?	Mururoa	shaft	WR	?
67. 12-08-76	?	?	Mururoa	shaft	WR	?
(1977)						
Eight tests during 1977, all at Mururoa.						
68. 02-19-77	?	23:29:58.94	138.846 W 21.834 S	shaft	WR	5.01 m_b 4.8 m_b (5 kt)
69. 03-19-77	?	23:00:58.36	138.913 W 21.891 S	shaft	WR	5.86 m_b 5.6 m_b (45 kt)
70. 07-06-77	?	22:59:58.52	138.954 W 21.780 S	shaft	WR	4.92 m_b 5.4 m_b (25 kt)
71. 11-12-77	?	01:30:00.0	Mururoa	shaft	WR	5.2 m_b (15 kt)
72. 11-24-77	NESTOR	16:59:58.37	138.884 W 21.896 S	shaft	WR	5.83 m_b 5.6 m_b (55 kt)
	A submarine landslide (and resultant tidal wave) was induced by this explosion.[102]					

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
73. 12-17-77	?	22:00:00.0	Mururoa	shaft	WR	5.1 m_b (10 kt)
74. 1975-1977[103]	?	?	Mururoa	?	?	?
75. 1975-1977	?	?	Mururoa	?	?	?

------------------------------ (1978) ------------------------------

Eight tests during 1978.

76. 02-27-78	?	23:00:00.0	Mururoa	shaft	WR	4.0 m_b (<1 kt)
77. 03-22-78	?	17:29:58.95	138.926 W 21.714 S	shaft	ERW?	4.78 m_b 5.1 m_b (10 kt)
78. 07-19-78[104]	?	18:00:00.0	Mururoa	shaft	WR	4.4 m_b (2 kt)
79. 07-26-78	?	23:00:00.0	Mururoa	shaft	WR	4.7 m_b (4 kt)
80. 11-02-78	?	18:00:00.0	Mururoa	shaft	WR	4.6 m_b (2 kt)
81. 11-30-78	?	17:31:58.48	138.949 W 21.866 S	shaft	WR	5.82 m_b 5.7 m_b (65 kt)
82. 12-17-78	?	18:04:00.0	Mururoa	shaft	WR	5.2 m_b (15 kt)
83. 12-19-78	?	16:56:59.98	138.945 W 21.769 S	shaft	WR	4.95 m_b 5.1 m_b (10 kt)

------------------------------ (1979) ------------------------------

Nine tests during 1979.

84. 03-01-79	?	17:24:00.0	Mururoa	shaft	WR	5.0 m_b (7 kt)
85. 03-09-79	?	16:37:00.0	Mururoa	shaft	WR	5.2 m_b (15 kt)
86. 03-24-79	?	16:27:58.79	138.909 W 21.830 S	shaft	WR	4.85 m_b 5.0 m_b (7 kt)
87. 04-04-79	?	18:06:59.10	138.741 W 21.812 S	shaft	WR	4.88 m_b 4.9 m_b (6 kt)
88. 06-18-79	?	23:26:58.02	138.456 W 22.140 S	shaft	WR	4.79 m_b 4.7 m_b (4 kt)
89. 06-29-79	?	18:55:58.75	138.927 W 21.798 S	shaft	WR	5.17 m_b 5.4 m_b (25 kt)
90. 07-25-79	?	17:56:58.50	138.940 W 21.880 S	shaft	WR	6.06 m_b 5.9 m_b (120 kt)

The largest and most widely recorded explosion between July 1976 and December 1981,[105] this detonation resulted in a major accident (see text).

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
91. 07-28-79	?	19:55:58.77	138.808 W 21.808 S	shaft	WR	4.71 m_b 5.2 m_b (15 kt)
92. 11-22-79	?	19:14:30	Mururoa	shaft	WR	4.7 m_b (4 kt)

------------------------------ (1980) ------------------------------

Thirteen tests during 1980.[106] Purpose of tests: more emphasis being given to tests of future systems.[107]

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
93. 02-23-80	?	18:03:00.0	Mururoa	shaft	WR	4.3 m_b (1 kt)
94. 03-03-80	?	17:56:00.0	Mururoa	shaft	WR	5.1 m_b (10 kt)
95. 03-23-80	?	19:36:58.49	138.928 W 21.864 S	shaft	WR	5.60 m_b 5.8 m_b (80 kt)
96. 04-01-80	?	19:30:58.68	138.763 W 21.854 S	shaft	WR	5.07 m_b 5.3 m_b (20 kt)
97. 04-04-80	?	18:32:58.61	138.808 W 21.906 S	shaft	WR	4.48 m_b 4.4 m_b (2 kt)
98. 06-16-80	?	18:26:58.56	138.904 W 21.864 S	shaft	WR	5.27 m_b 5.4 m_b (25 kt)
99. 06-21-80	?	17:01:00.0	Mururoa	shaft	ERW[108]	5.0 m_b (9 kt)
100. 07-06-80	?	17:26:58.96	138.861 W 21.845 S	shaft	WR	4.65 m_b 4.8 m_b (5 kt)
101. 07-19-80	?	23:46:58.51	138.949 W 21.855 S	shaft	WR	5.67 m_b 5.8 m_b (80 kt)
102. 11-25-80	?	17:53:00.0	Mururoa	shaft	WR	4.5 m_b (2 kt)
103. 12-03-80	?	17:32:58.48	138.945 W 21.874 S	shaft	TN 70	5.57 m_b 5.6 m_b (50 kt)
104. ??-??-80[109]	?	?	Mururoa	?	?	?
105. ??-??-80	?	?	Mururoa	?	?	?

------------------------------ (1981) ------------------------------

Twelve tests during 1981.[110] Purpose of 1981 tests: the nuclear tests are increasingly orientated to the medium and long term systems.[111]

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
106. 02-27-81	?	23:28:00.0	Mururoa	shaft	WR	5.0 m_b (8 kt)
107. 03-06-81[112]	?	17:27:00.0	Mururoa	shaft	WR	4.5 m_b (2 kt)
108. 03-28-81	?	17:22:59.17	138.674 W 21.780 S	shaft	WR	4.77 m_b 4.8 m_b (5 kt)
109. 04-10-81	?	17:56:59.03	138.969 W 21.775 S	shaft	WR	4.77 m_b 5.0 m_b (8 kt)

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
110. 07-08-81	?	22:22:58.81	139.049 W 21.781 S	shaft	WR	5.10 m_b 5.3 m_b (20 kt)
111. 07-11-81	?	17:17:00.0	Mururoa	shaft	WR	5.0 m_b (8 kt)
112. 07-18-81	?	17:43:00.0	Mururoa	shaft	WR	4.5 m_b (2 kt)
113. 08-03-81	?	18:32:58.58	138.900 W 21.833 S	shaft	ERW[113]	5.09 m_b 5.2 m_b (15 kt)
114. 11-11-81	?	17:06:58.65	138.991 W 21.833 S	shaft	not ERW[114]	4.65 m_b 4.6 m_b (3 kt)
115. 12-05-81	?	16:57:59.00	138.774 W 21.848 S	shaft	not ERW	4.71 m_b 4.8 m_b (5 kt)

This was the first test conducted in the center of the atoll (lagoon).

116. 12-08-81	?	16:46:58.70	138.896 W 21.808 S	shaft	not ERW	5.05 m_b 5.2 m_b (15 kt)
117. ??-??-81[115]	?	?	Mururoa	?	?	?

------------------------------ (1982) ------------------------------

Six tests during 1982.[116] Purpose of tests: primarily to research new formulas, higher performance warheads, and more economical use of fissile material. Work progressed on both the enhanced radiation and low blast aspects of the ERW.[117]

118. 02-20-82	?	17:33	Mururoa	?	WR	4.6 m_b (3 kt)
119. 03-20-82	?	17:02:57.8	138.941 W 21.996 S	shaft	ERW[118]	5.2 m_b (15 kt)
120. 06-27-82	?	17:00:00.0	Mururoa	shaft	WR	4.4 m_b (2 kt)

This test was observed by the Tazieff scientific mission, which brought monitoring instruments to check for venting. As the yield of the device was so small, little could be learned about the risks during the normal test program, when yields were substantially greater.[119]

121. 07-01-82	?	17:01:58.8	139.050 W 21.766 S	shaft	WR	5.3 m_b (20 kt)
122. 07-21-82	?	17:13:00.0	Mururoa	shaft	WR	4.5 m_b (2 kt)
123. 07-25-82	?	18:01:58.1	138.943 W 21.864 S	shaft	WR	5.7 m_b (55 kt)

------------------------------ (1983) ------------------------------

Nine tests during 1983.[120] The purpose of 1983 tests was the development and realization of weapons for next ten years, and definition of weapons for the long term, 1994-2000.[121]

124. 04-19-83	?	18:52:58.4	138.906 W 21.847 S	shaft	WR	5.5 m_b (40 kt)

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
125. 04-25-83[122]	?	17:03:00	Mururoa	shaft	WR	4.2 m_b (1 kt)
126. 05-25-83	?	17:30:58:2	138.918 W 21.895 S	shaft	WR	5.6 m_b (40 kt)
127. 06-18-83[123]	?	17:31:00	Mururoa	shaft	WR	4.6 m_b (3 kt)
128. 06-28-83	?	17:45:58.6	138.917 W 21.745 S	shaft	WR	5.5 m_b (35 kt)
129. 07-20-83	?	20:30:00.0	Mururoa	shaft	WR	5.0 m_b (10 kt)
130. 08-04-83	?	17:13:58.2	138.922 W 21.835 S	shaft	WR	5.0 m_b (8 kt)
131. 12-03-83	?	16:58:00.0	Mururoa	shaft	WR	4.7 m_b (4 kt)
132. 12-07-83	?	17:28:00.0	Mururoa	shaft	WR	5.2 m_b (15 kt)

------------------------------- (1984) -------------------------------

Eight tests during 1984. The purpose of 1984 tests: the "validation" of the TN 71 (improved warhead for the M4), testing of TN 81 (improved warhead for the ASMP), and research on a warhead for the Hadès missile.[124]

133. 05-08-84	?	17:26	Mururoa	shaft	WR	5.3 m_b (20 kt)
134. 05-12-84	?	17:30:58.3	138.961 W 21.852 S	shaft	WR	5.7 m_b (55 kt)
135. 06-12-84	?	17:16:00.0	Mururoa	shaft	WR	4.5 m_b (2 kt)
136. 06-16-84	?	17:43:57.9	138.992 W 21.933 S	shaft	WR	5.5 m_b (35 kt)
137. 10-27-84	?	17:16:00.0	Mururoa	shaft	WR	4.7 m_b (3 kt)
138. 11-02-84	?	20:44:00.0	Mururoa	shaft	WR	5.5 m_b (35 kt)
139. 12-01-84	?	16:51:00.0	139.000 W 22.000 S	shaft	WR	4.2 m_b (1 kt)
140. 12-06-84	?	17:28:58.3	138.954 W 21.890 S	shaft	WR	5.6 m_b (55 kt) 5.7 m_b[125]

------------------------------- (1985) -------------------------------

The purpose of the eight tests in 1985: testing of the TN 81, a warhead for Hadès, and designs for the next decade.[126]

141. 04-30-85	?	17:29:00.0	Mururoa	shaft	WR	5.1 m_b (15 kt)
142. 05-08-85	?	20:28:00.0	Mururoa	shaft	WR	5.8 m_b (90 kt) 150 kt[127]
143. 06-03-85	?	17:30:00.0	Mururoa	shaft	WR	5.1 m_b (10 kt)
144. 06-07-85	?	17:40:00.0	Mururoa	shaft	WR	4.8 m_b (5 kt)

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
145. 10-24-85	HÉRO	17:50:00.0	Mururoa	shaft/-700 m[128]	TN 81?[129]	4.5 m_b (2 kt)
146. 10-26-85	?	16:35:00.0	Mururoa	shaft	WR	5.3 m_b (20 kt)
147. 11-24-85	?	16:30:00.0[130]	Mururoa	shaft	WR	4.8 m_b (5 kt)
148. 11-26-85	?	17:42:00.0	Mururoa	shaft	Hadès	5.6 m_b (55 kt)
(1986)						
Eight tests during 1986.						
149. 04-26-86	?	17:01:56.6	139.120 W 22.150 S	shaft	WR	4.8 m_b (5 kt)
150. 05-06-86	?	16:58:00.0	Mururoa	shaft	WR	4.7 m_b (5 kt)
151. 05-27-86	?	17:15:00.0	Mururoa	shaft	WR	4.7 m_b (4 kt)
152. 05-30-86	?	17:24:58.2	139.100 W 21.913 S	shaft	WR	5.4 m_b (30 kt)
153. 11-10-86	?	16:58:00.0	Mururoa	shaft	WR	4.9 m_b (6 kt)
154. 11-12-86	?	17:01:58.5	139.068 W 21.894 S	shaft	WR	5.3 m_b (25 kt)
155. 12-06-86	?	17:10:00.0	Mururoa	shaft	WR	5.0 m_b (9 kt)
156. 12-10-86	?	17:14:58.6	138.986 W 21.877 S	shaft	WR	5.5 m_b (30 kt)
(1987)						
Eight tests during 1987.						
157. 05-05-87	?	16:58:00.0	Mururoa	shaft	WR	4.8 m_b (5 kt)
158. 05-20-87	?	17:05:00.0	Mururoa	shaft	WR	5.4 m_b (30 kt)
159. 06-06-87	?	18:00:00.0	Mururoa	shaft	WR	4.5 m_b (3 kt)
160. 06-21-87	?	17:54:58.4	138.844 W 21.984 S	shaft	WR	5.2 m_b (15 kt)
161. 10-23-87	?	16:50:00.0	Mururoa	shaft	WR	5.6 m_b (50 kt)
162. 11-05-87	?	17:29:55.5	138.970 W 22.340 S	shaft	WR	5.2 m_b (20 kt)
163. 11-19-87	?	16:30:58.5	139.037 W 21.878 S	shaft	WR	5.7 m_b (60 kt)
164. 11-29-87	?	17:59:00.0	Mururoa	shaft	WR	4.6 m_b (3 kt)

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield

------------------------------- (1988) -------------------------------

Eight tests during 1988; seven at Mururoa, one at Fangataufa.

# and Date	Event Name	Time (GMT)	Location	Type/Height of Burst	Purpose	Yield
165. 05-11-88	?	16:59:58.1	139.107 W 21.927 S	shaft	WR	5.3 m_b (20 kt)
166. 05-25-88	?	17:00:58	139.027 W 21.899 S	shaft	WR	5.8 m_b (80 kt)
167. 06-16-88	?	17:14:57	Mururoa	shaft	WR	4.8 m_b (5 kt)
168. 06-23-88	?	17:30:58.5	139.042 W 21.928 S	shaft	WR	5.4 m_b (30 kt)
169. 10-25-88	?	17:00:00	Mururoa	shaft	WR	4.4 m_b (2 kt)
170. 11-05-88	?	16:29:57.6	139.029 W 22.052 S	shaft	WR	5.6 m_b (50 kt)
171. 11-23-88	?	17:00:58.5	139.029 W 22.908 S	shaft	WR	5.6 m_b (40 kt)
172. 11-30-88	?	17:54:54.3	138.91 W (F) 22.90 S	shaft	WR	5.9 m_b (100 kt)

First underground test at Fangataufa atoll since 1975.

KEY TO TABLE 1:

Date and Time: All dates are expressed as month-day-year. Times are origin times, expressed in hours:minutes:seconds: fraction of a second. All times have been converted to Greenwich Mean Time (GMT), also known as Universal Time (UT).

Location: Exact coordinates are provided where known. Coordinates are expressed in two different ways, as cited in the original text: prior to 1966 all coordinates were cited the form of, for example, 5:03:17.9 E (thus 5 degrees, 3 minutes, 17.9 seconds, East). After 1966, all coordinates are decimalized, for example 138.200 W. Where applicable, M = Mururoa, F = Fangataufa.

Purpose: Weapons Related tests are designated by the symbol WR. If the name of warhead being tested is known (or suspected), it is so indicated in the table. Weapons Effects tests are designated WE. Tests partially studied for application of peaceful uses are designated APEX. Safety tests are designated SE.

Yield: Yields in kilotons (kt) or megatons (Mt) are provided where known. Magnitude (m_b) of the test is provided when known.

ENDNOTES FOR TABLE 1:

1. Unless indicated to the contrary, data on tests 1, 2, 3 from, Commissariat à l'Énergie Atomique (CEA), Rapport Annuel 1960 (Paris: CEA, 1961), pp. 137, 141; French Embassy, release no. 891 (short title); Nicholas Vichney, "Quelques Aspects Scientifiques et Techniques de la Bombe A Française," Nature, no. 3299, March 1960, p. 121; DOE list (short title).

2. French Embassy, release no. 891. DOE list puts tower at 350 ft high.

3. CEA, Rapport Annuel 1960 (Paris: CEA, 1961), p. 137; French Embassy, release no. 891; DOE list; Bertrand Goldschmidt, The Atomic Adventure: Its Political and Technical Aspects, trans. by Peter Beer (New York: Macmillan Company, 1964), p. 122. Other sources give a yield of 65 kt: Yves Rocard, "La Naissance de la Bombe Atomique Française," La Recherche, No. 141, February 1983, p. 206; David Marsh, "France Tests its Atomic Might," New Scientist, 14 February 1985, pp. 18, 22. One source gives yield of 79 kt: Nicolas Vichney, "Les Premiers Enseignements de l'Experience de Reggane," Le Monde, 9 March 1960.

4. Nicholas Vichney, "Quelques Aspects Scientifiques et Techniques de la Bombe A Française," Nature, no. 3299, March 1960, p. 121.

5. According to allegations made on Algerian TV; Agence France Presse (AFP) (Paris), 11 May 1985.

6. FOA printout (short title). However a French Ministry of Armed Forces communiqué on 4 April 1960 gives time as 06:15.

7. French Embassy, release no. 891 calls it "five or six times less powerful than the first test", while Nicolas Vichney, "La Seconde Bombe Atomique Française," Le Monde, 2 April 1960, refers to it as "three times less powerful than the first." The following sources call it low- or small-power: DOE list; Ministry of Armed Forces communiqué dated 4 April 1960.

8. Aviation Studies Atlantic, Nuclear Weapons Data File (London: Aviation Studies Atlantic, circa 1985), Section 6, p. 4.

9. Nicolas Vichney, "La Seconde Bombe Atomique Française," Le Monde, 2 April 1960.

10. French Embassy, release no. 891.

11. Nicolas Vichney, "La Troisième Bombe Atomique Française a Explosé Mardi a 7H.30," Le Monde, 28 December 1960. DOE list, and French Embassy, release no. 891, refer to it as low- or small-power.

12. Nicolas Vichney, "La Troisième Bombe Atomique Française a Explosé Mardi a 7H.30," Le Monde, 28 December 1960.

13. French Embassy, release no. 891.

14. D.G. Brennan, "The Risks of Spreading Weapons: A Historical Case," Arms Control and Disarmament, Vol. 1, 1968, pp. 59-60. DOE list calls it low- or small-power.

15. According to one source, this test resulted in accidental contamination of French soldiers due to the malfunction of the chemical explosive used as a detonator for the nuclear device; Jean Planchais, "Apres les Accidents de Reggane et du Hoggar, les Mesures de Securite Doivent etre Renforcees avant toute Nouvelle Explosion Nucleaire," Le Monde, 1 July 1962.

16. D.G. Brennan, "The Risks of Spreading Weapons: A Historical Case," Arms Control and Disarmament, Vol. 1, 1968, pp. 59-60.

17. Tests that were part of CEA APEX series have two names attributed, a precious stone and a girl's name, the latter being the APEX designation. Stephens, French-American, 1972, p. 6 (short title), lists four such APEX tests: MONIQUE (known to be the same as the SAPHIR test); GEORGETTE (thought to be the same as GRENAT); MICHELE (thought to be the same as OPALE); and CARMEN (with no obvious counterpart, CARMEN had a 15.4 kt yield, 635 m depth, 52 m^3 volume of detonation chamber, and 2.3 m equivalent radius of detonation chamber).

18. Unless indicated to the contrary, two main sources were used for data on French underground tests in Algeria. Firstly, Duclaux and Michaud, "Conditions Expérimentales," 1970, p. 189 (short title), provided data on event names, detailed times of detonation, precise epicenters, and generic yields (e.g., <20 kt). Secondly, I.G. Stimpson (U.K. Atomic Weapons Establishment), Source Parameters of Explosions in Granite at the French Test Site in Algeria (London: HMSO, July 1988), AWE Report no. 0 11/88, p. 12, provided revised estimates of magnitude (m_b) (accurate to two decimal places) for six of the underground tests, and hence also the derived kt yields. DOE list provided generic yield estimates (e.g., "weak", "middle", etc.).

19. According to one source, these underground tests were conducted in caverns in the Hoggar mountains; David Marsh, "France Tests its Atomic Might," New Scientist, 14 February 1985, pp. 18, 22. DIRCEN, "Dossier no. 1" (short title), section 1/11, p. 1, states that testing was conducted in underground galleries.

20. Bertrand Goldschmidt, The Atomic Adventure: Its Political and Technical Aspects, trans. by Peter Beer (New York: Macmillan Company, 1964), p. 155.

21. One source states that the detonation of this "powerful underground explosion" resulted in an incident whereby radioactive vapor escaped through a fissure in the rock, contaminating some of the observers, including the two ministers present; Bertrand Goldschmidt, The Atomic Adventure: Its Political and Technical Aspects, trans. by Peter Beer (New York: Macmillan Company, 1964), p. 122. Another source states that the order was given to proceed with the detonation, despite "adverse winds", because of the presence of these two ministers, one being the Ministre des Armees; Jean Planchais, "Apres les Accidents de Reggane et du Hoggar, les Mesures de Securite Doivent etre Renforcees avant toute Nouvelle Explosion Nucleaire," Le Monde, 1 July 1962, cited in, Michel Haag, France's Low Awareness of Accidental Nuclear War Dangers, Technical Report No. 5 (Santa Barbara, CA: Nuclear Age Peace Foundation, September 1987), p. 2.

22. Other estimates include <20 kt; Duclaux and Michaud, "Conditions Expérimentales," 1970, p. 189, and "weak"; DOE list.

23. The published yield of 52 kt was obtained from, Swedish Institute for Peace and Conflict Research, Seismic Methods for Monitoring Underground Explosions (Stockholm: SIPRI, 1968), cited in, Stimpson, op. cit., p. 11. Other estimates include >20 kt; Duclaux and Michaud, "Conditions Expérimentales," 1970, p. 189, and "middle": DOE list.

24. Letter Peter D. Marshall (U.K. Atomic Weapons Establishment, Blacknest) to A.S. Burrows, 5 October 1988; "Clearly the two largest tests ever conducted by the French [at Hoggar], based on the seismic m_b and M_s, are SAPHIR and RUBIS. At the SIPRI meeting of 1966 the French delegate gave the m_b and yield of four French tests. The two largest yields are about 120 and 50 kt, [thus by] matching their m_b values one is drawn to the conclusion that SAPHIR is about 120 kt, and RUBIS about 50 kt."

25. Other estimates include: <20 kt; Duclaux and Michaud, "Conditions Expérimentales," 1970, p. 189, and "weak"; DOE list.

26. According to Stephens, French-American, 1972, p. 6, MICHELE test had a yield of 3.6 kt, at a depth of 353 m, a volume of detonation chamber of 125 m^3, equivalent radius of detonation chamber at 3.1 m, and radii of pulverized zone at 14 m. Assuming that it is no mere coincidence that OPALE and MICHELE have a similar yield (at 3.7 and 3.6 kt respectively), then they are one and the same.

27. Published yield of 117 kt, cited in, Stephens, French-American, 1972, p. 6. Other estimates include >20 kt; Duclaux and Michaud, "Conditions Expérimentales," 1970, p. 189, and "middle"; DOE list.

28. See explanation in note 24 (letter from Peter D. Marshall). In this letter Marshall further stated that "Other sources [Stephens] indicate that the explosion MONIQUE is 117 plus/minus 12 kt; clearly there were not two explosions close to this yield if the seismic evidence is to be believed."

29. According to Stephens, French-American, 1972, p. 6, MONIQUE test had a yield of 117 kt, depth of 785 m, volume of detonation chamber of 66.7 m^3, equivalent radius of detonation chamber at 2.5 m, and radii of pulverized zone at 45.6 m.

30. Other estimates include <20 kt; Duclaux and Michaud, "Conditions Expérimentales," 1970, p. 189, and "weak"; DOE list.

31. Other estimates include a 60 kt plutonium bomb; "La Défense Nationale: Les Precedents Tirs Français," Le Figaro, 13 June 1974, and <20 kt; Duclaux and Michaud, "Conditions Expérimentales," 1970, p. 189, and "weak"; DOE list.

32. According to Stephens, French-American, 1972, p. 6, GEORGETTE test had a yield of 13 kt; a depth of 403 m; a volume of detonation chamber at 58.5 m^3; equivalent radius of detonation chamber of 2.4 m; and radii of pulverized zone at 23 m. Assuming that it is no mere coincidence that GRENAT and GEORGETTE are both 13 kt, then they are one and the same.

33. Although all the locations for the 44 atmospheric tests 1966-1974 are indicated as Mururoa and Fangataufa, some of these were nevertheless conducted over adjacent ocean areas (including near the Tureia and Gambier atolls). According to one source, 15 tests were conducted over the South Pacific Ocean; European Parliament, Session Documents, 1988-89, Series A, Document no. A2-0283/88, 1 December 1988, p. 7.

34. Firstly, unless indicated to the contrary, the FOA printout (short title) is used for all times (GMT), where known, and coordinates (if precise), and sometimes magnitude (m_b) values. Secondly, DOE list (short title) is used for the location (Mururoa or Fangataufa), type of test (e.g. barge, balloon), and generic yield estimates (such as "low", "intermediate" etc.).

35. Sources for 1966 tests: unless indicated to the contrary, data on yields obtained from, P. Parfond, "La Campagne de Tirs 1966," TAM, 19 September 1968, p. 37. Data on type of burst (e.g. barge) and type of device tested (e.g. pure plutonium fission) obtained from, Lt-Colonel Destefanis, "Les Expérimentations Nucléaires dans le Pacifique," Revue de Défense Nationale, July 1967, pp. 1210-1211.

36. Another source puts yield at 20-40 kt; AFP, "France's Fifth Nuclear Explosion in the Pacific," dispatch dated 14 September 1966. DOE list calls the yield "small".

37. Greenpeace, "Testimony of Edwin Haoa," March 1987, p. 2.

38. 100 km south of Mururoa, over the ocean; Bengt Danielsson, "Under a Cloud of Secrecy: The French Nuclear Tests in the Southeastern Pacific," Ambio, Vol. 13, No. 5-6, 1984, p. 336. This location is closer to Fangataufa than to Mururoa. However, DOE list still refers to the location as Mururoa.

39. "Une Bombe 'Opérationnelle' est Larguée d'un Mirage IV en Polynésie," Le Monde, 21 July 1966. Another source puts the yield of this "operational" bomb at 60-80 kt; AFP, "France's Fifth Nuclear Explosion in the Pacific," dispatch dated 14 September 1966. DOE list calls the yield "small". Paul Jackson, "Deterrent at the Crossroads," Armed Forces, Vol. 4, no. 3, March 1985, p. 101, refers to a "trial 18 kt weapon".

40. "Une bombe 'Opérationnelle' est Larguée d'un Mirage IV en Polynésie," Le Monde, 21 July 1966, states that detonation was in the lower atmosphere. Bengt Danielsson, "Under a Cloud of Secrecy: The French Nuclear Tests in the Southeastern Pacific," Ambio, Vol. 13, No. 5-6, 1984, p. 336, states that the bomb was dropped from an aircraft at 16,000 m. All sources indicate that a Mirage IVA aircraft was used, except, P. Parfond, "La Campagne de Tirs 1966," TAM, 19 September 1968, p. 37, names the Mirage III aircraft.

41. AFP, "France's Fifth Nuclear Explosion in the Pacific," dispatch dated 14 September 1966. Another source states the GANYMÈDE test was designed to check the security of nuclear weapons throughout their storage and transport; French Embassy (N.Y.), "The 1966 French Nuclear Tests Series," M.286, [illegible] June 1967.

42. The only major difference between the AN 11, and the AN 22 which replaced it, was the addition of security devices (PAL).

43. Bengt Danielsson, "Under a Cloud of Secrecy: The French Nuclear Tests in the Southeastern Pacific," Ambio, Vol. 13, No. 5-6, 1984, pp. 336-337.

44. Other estimates include 150 kt; Michel Haag, France's Low Awareness of Accidental Nuclear War Dangers, Technical Report No. 5 (Santa Barbara, CA: Nuclear Age Peace Foundation, September 1987), p. 2; and, 100-200 kt; AFP, "France's Fifth Nuclear Explosion in the Pacific," dispatch dated 14 September 1966; and, "small"; DOE list.

45. CEA, "Les Principales Activités du Commissariat à l'Énergie Atomique," CEA Notes d'Information, report no. 33 971, January 1970, p. 16.

46. Danielsson, Poisoned Reign, p. 102 (short title).

47. Greenpeace, "French Nuclear Weapons Testing in the Pacific," press briefing on 4 September 1985, p. 2; Danielsson, Poisoned Reign, p. 102.

48. Reports at the time stated, erroneously, that lithium-6 deuteride (deutériure de lithium) was used in this boosting process; Nicolas Vichney, "L'Explosion d'Une Puissante Bombe Dopée," Le Monde, 6 October 1966, p. 10.

49. "La Defense Nationale: Les Precedents Tirs Francais," Le Figaro, 13 June 1974. However another source states that although one test involved "un engin expérimental à vocation thermonucléaire," the other two tests concerned continuing work on the enhancement of the yield of boosted fission weapons; Le Monde, 1 June 1967. In any case, the tests still involved, for the first time, devices using highly-enriched U-235.

50. Abbé Toulat, La Bombe ou la Vie (Paris: Fayard, 1969), pp. 5-6.

51. Jacques Robert (Director of CEA/DAM), "La Direction des Applications Militaires du Commissariat à l'Énergie Atomique: Réalisations et Perspectives," Revue de Défense Nationale, March 1970, p. 378.

52. AFP, "La 10ème Explosion Nucléaire Française dans le Pacifique," 7 July 1968.

53. CEA, "Les Principales Activités du Commissariat à l'Énergie Atomique," CEA Notes d'Information, report no. 33 971, January 1970, p. 16.

54. "La Troisième Campagne d'Essais Nucléaires dans le Pacifique est Terminée," Le Monde, 11 September 1968.

55. Jacques Robert (Director of CEA/DAM), "La Direction des Applications Militaires du Commissariat à l'Énergie Atomique: Réalisations et Perspectives," Revue de Défense Nationale, March 1970, p. 380.

56. CEA, "Les Principales Activités du Commissariat à l'Énergie Atomique," CEA Notes d'Information, report no. 33 971, January 1970, p. 16.

57. AFP (Papeete), "Conference de Presse du Directeur des Centres d'Expérimentations Nucléaires Françaises," 28 August 1968. The device was also said to compare in size to a "Simca 1000" car; "La Première Bombe 'H' Française Avait une Puissance de 2 Mégatonnes," Le Monde, 29 August 1968; "Succès Remarquable de la Première Explosion Thermonucléaire Française," Air et Cosmos, 7 September 1968.

58. Bengt Danielsson, "Under a Cloud of Secrecy: The French Nuclear Tests in the Southeastern Pacific," Ambio, Vol. 13, No. 5-6, 1984, p. 338.

59. Jacques Robert (Director of CEA/DAM), "La Direction des Applications Militaires du Commissariat à l'Énergie Atomique: Réalisations et Perspectives," Revue de Défense Nationale, March 1970, p. 380.

60. Bengt Danielsson, "Under a Cloud of Secrecy: The French Nuclear Tests in the Southeastern Pacific," Ambio, Vol. 13, No. 5-6, 1984, p. 338.

61. "La France se Livrera à de Nouveaux Essais Thermonucléaires en 1969 dans le Pacifique," Le Monde, 31 October 1968.

62. "La Defense Nationale: Les Precedents Tirs Francais," Le Figaro, 13 June 1974; Danielsson, Poisoned Reign, p. 136.

63. AFP (Paris), release no. 152, 15 May 1970; AFP (Paris), release no. 163, 6 August 1970.

64. "La France Procédera Jusqu'au 15 Aout à Huit Expériences Nucléaires en Polynésie," Le Monde, 16 May 1970.

65. This test concerned work on a fission primary for a future French thermonuclear warhead; AFP (Paris), release no. 139, 22 May 1970.

66. AFP (Paris), release no. 152, 27 July 1970 (also calls it "high/strong power"). The following sources call it 1 megaton: DOE list; and, Danielsson, Poisoned Reign, p. 145.

67. According to Le Monde, 17 August 1971. DOE list calls it a "hydrogen bomb".

68. Danielsson, Poisoned Reign, p. 145.

69. Sources for 1971 tests: Unless indicated to the contrary, data on first three tests obtained from "Essai d'une Bombe Atomique de Faible Puissance en Polynésie Française," Le Monde, 10 August 1971, and data on last two from Le Monde of 17 August 1971.

70. French Embassy Press and Information Service (N.Y.), "The French Nuclear Tests at the Pacific Tests Center," 1971, p. 2; AFP, "La Prochaine Campagne Nucléaire Française," 2 June 1971; CEA, Revue de la Presse Francaise, 15 June 1971; "La Defense Nationale: Les Precedents Tirs Francais," Le Figaro, 13 June 1974.

71. French Embassy Press and Information Service (N.Y.), "The French Nuclear Tests at the Pacific Tests Center," 1971, p. 2 (to test elements and prototypes of the MR 60); "Les Applications Militaires Thermonucléaires Feront l'Objet de la Campagne de Tirs de 1971," Le Monde, 14 July 1970.

72. AFP, "La Prochaine Campagne Nucléaire Française," release no. 148, 2 June 1971.

73. AFP, "La Prochaine Campagne Nucléaire Française," 2 June 1971. 15 kt according to, "La Defense Nationale: Les Precedents Tirs Français," Le Figaro, 13 June 1974.

74. CEA, Revue de la Presse Francaise, 15 June 1971.

75. Le Monde, 17 August 1971.

76. Test of fission primary for TN 60 thermonuclear warhead.

77. Test of fission primary for TN 60 thermonuclear warhead.

78. CEA, 1 September 1971; Le Monde, 17 August 1971 (about a Mt).

79. Two sources mention that a "security test" (like the one of 07-21-66) was planned for the 1971 test series: "Nouvelle Campagne Française de Tirs Nucléaires dans le Pacifique," Le Monde, 3 June 1971; AFP, "La Prochaine Campagne Nucleaire Francaise," release no. 148, 2 June 1971. This security test probably involved the TN 60/61 warhead.

80. "La Défense Nationale: Les Precedents Tirs Français," Le Figaro, 13 June 1974.

81. Le Monde, 12-13 November 1972.

82. Test of fission primary for TN 60 thermonuclear warhead.

83. "Le Tir du Dimanche 16 Juin Était de Faible Puissance," Le Monde, 19 June 1974.

84. According to Defense Minister Soufflet and another unnamed government spokesmen, cited in, Danielsson, Poisoned Reign, pp. 204, 206.

85. Test of a fission primary for the thermonuclear MIRVed TN 70 warheads of the M4 missile; "La France a Franchi une Étape Vers la Mis au Point de Missiles à Têtes Multiples," Le Monde, 15 August 1974. This completes a series of low-power tests started last year; Jacques Isnard, "La Puissance du Dernier Essai Nucléaire de Mururoa a été de 5 Kilotonnes," Le Monde, 21 June 1974.

86. "Un Essai Nucléaire Français a eu lieu Dimanche en Polynésie," Le Monde, 18 June 1974.

87. Jacques Isnard, "La Puissance du Dernier Essai Nucléaire de Mururoa a été de 5 Kilotonnes," Le Monde, 21 June 1974.

88. A test of an operational configuration of the TN 70 warhead; AFP, "La Huitieme Campagne d'Essais Nucléaires Français au Pacifique Terminée," release no. 104, 16 August 1974. Managed to miniaturize certain components.

89. Possible test of fission primary for the ASMP missile; "La France a Franchi une Étape Vers la Mis au Point de Missiles à Têtes Multiples," Le Monde, 15 August 1974.

90. It is unclear whether there was any nuclear detonation in this case, as no sources mention any nuclear yield. It is clear that a "security test" (i.e. of the locking/safety apparatus, like the test of 21 July 1966) was planned for 1974, but it is not known if it is one and the same as this test of 26 July 1974. It is known that the CEA was dissatisfied with the results of the 6.6 kt yield from the AN 52 dropped by the Mirage IIIE on 28 August 1973, i.e. it was either supposed to be greater, or it was supposed to be nil. Thus this test was supposed to rectify the situation.

91. Although not listed by FOA printout, this test is listed by: UPI, "New French Nuclear Test in Pacific is Reported," New York Times, 30 July 1974; and, "La France a Franchi une Étape Vers la Mis au Point de Missiles à Têtes Multiples," Le Monde, 15 August 1974.

92. AFP, "Essai Nucleaire a Mururoa: Sixieme et Dernier Tir?" release no. 146, 15 August 1974; "La France a Franchi une Étape Vers la Mis au Point de Missiles à Têtes Multiples," Le Monde, 15 August 1974.

93. Unless indicated to the contrary, three sources are relied upon for data on underground tests 1975-1988. Firstly, Table 1 makes extensive use of the printout entitled "Underground Nuclear Explosions in the Tuamotu Archipelago," dated 25 January 1989, compiled by Warwick D. Smith of the Seismological Observatory, Geophysics Division, New Zealand Department of Scientific and Industrial Research (DSIR). The DSIR recorded the date, time, magnitude, and yield of French tests, as recorded at the Rarotonga seismograph station in the Cook Islands (which is particularly sensitive to explosions from the Tuamotu Archipelago). Table 1 uses the DSIR printout (short title) for the magnitude (m_b) of each test, from which DSIR derived the yield, to the nearest 5 kt. Under the "Yield" heading in Table 1, the DSIR figure is quoted first (except for some tests, see below), in the following format: 5.2 m_b (15 kt), as an example. Secondly, the FOA printout (short title) was used as a source for tests 1975-1987, and providing times of detonation to the closest one-tenth of a second (e.g. 17:29:59.1), geographical coordinates, and sometimes m_b values (not accompanied by a kt yield figure). A third source was used for select tests 1976-1981; P. D. Marshall, R. C. Lilwall, P. J. Warburton (U.K. Atomic Weapons Establishment), Body Wave Magnitudes and Locations of French Underground Explosions at the Mururoa Test Site (London: HMSO, November 1985), AWRE Report no. O 12/85, pp. 7-8. Using seismic wave arrival time and amplitude data from the International Seismological Centre, Marshall et al. analyzed the data "using a joint epicentre technique (JED) to relocate the epicentres, and a least square analysis (LSMF) of amplitude data to provide consistent estimates of the seismic magnitude." Table 1 incorporates the revised data of Marshall et al., including precise times of detonation to the closest one-hundredth of a second (e.g. 17:29:59.14), coordinates, and revised m_b values (accuracy provided to two decimal places, e.g. 5.23 m_b). In these cases, the Marshall et al. figure is quoted before the DSIR printout figure, as it is considered more accurate.

94. Shaft was located on the southern part of the rim; Danielsson, Poisoned Reign, p. 213.

95. According to a French Ministry of Defense statement on 9 June 1975; Danielsson, Poisoned Reign, p. 212.

96. Ibid.

97. Shaft was located on the northern part of the rim; Danielsson, Poisoned Reign, p. 214.

98. "Deuxième Tir Nucléaire Souterrain de la France en Polynésie," Le Monde, 28 November 1975.

99. While DSIR printout only registers the test of 07-11-76, three other French tests are thought to have occurred in 1976, according to FOA printout. Furthermore, the French Defense Minister confirmed the two tests in July 1976 ("Deux Tirs Nucléaires Ont eu Lieu à Mururoa," Le Monde, 24 July 1976), while Le Monde of 10 December 1976 confirmed the test in December.

100. Test of a "miniaturized and hardened" warhead; Le Monde, 6 April 1976.

101. Cited in, Danielsson, Poisoned Reign, p. 245.

102. According to the 1983 official report by the Government Commissary for the Prevention of Natural Disasters, Haroun Tazieff, cited in, Danielsson, Poisoned Reign, p. 246.

103. According to "Dossier no. 1" (short title), published by the French testing agency DIRCEN, 14 underground tests were conducted 1970-end 1977, two more than previously thought. Since France only resumed underground testing in 1975, it is assumed that these two extra tests were conducted in 1975, 1976, or 1977. Le Point of 16 June 1975 stated that the first explosion in 1975 would be "followed in quick succession by four others," implying that the extra tests might have been conducted in 1975 (if this was the case, they must have been conducted at Mururoa, not Fangataufa, as DIRCEN has confirmed that only two underground tests took place at Fangataufa in the 1970s). One source claims that France conducted two underground tests in 1974, a year before France officially moved its testing program underground; Aviation Studies Atlantic, Nuclear Weapons Data File (London: Aviation Studies Atlantic, circa 1985), Section 6, p. 6.

104. This test was detected by FOA. The Geological Survey of Canada (Yellowknife seismological array) and DSIR both subsequently confirmed this test (although changing reels at the time, DSIR nevertheless still picked up a partial signal). According to Dr. Robert North, Geological Survey of Canada, subsequent analysis of DSIR records revealed a weak T-phase signal, corresponding to yield of <2 kt.

105. Marshall et al., op. cit., p. 4.

106. 13 tests according to DIRCEN, "Dossier no. 1," only 11 according to DSIR printout and FOA printout.

107. The advancement of the studies on the M4 and ASMP warheads has permitted a reduction in the proportion of tests allocated to these warheads, since late 1979; CEA, Rapport Annuel 1981 (Paris: CEA, 1982), p. 51. One source claims that three tests of the M4 warhead (TN 70) were conducted in 1980, including the December 3 test concerning the "hardening" of the warhead; French Embassy (N.Y.), "Test of Nuclear Missile Successful," News and Comments from France, 10 December 1980.

108. According to Richard Eder, "Neutron Warhead Tested by France; No Production Set," New York Times, 27 June 1980, p. A4.

109. According to DIRCEN, "Dossier no. 1," 13 tests were conducted in 1980, two more than previously thought.

110. 12 tests according to DIRCEN, "Dossier no. 1," only 11 according to FOA printout and DSIR printout.

111. Since the development of the M4 and ASMP warheads is said to be progressing well; CEA, Rapport Annuel 1981 (Paris: CEA, 1982), p. 51.

112. This test was detected by FOA. The Geological Survey of Canada (Yellowknife seismological array) and DSIR both subsequently confirmed this test (although changing reels at the time, DSIR nevertheless still picked up a partial signal). According to Dr. Robert North, Geological Survey of Canada, subsequent analysis of DSIR records revealed a weak T-phase signal, corresponding to yield of <2 kt.

113. This was a test of a neutron bomb, according to a 1982 French Defense Ministry "position paper"; Danielsson, Poisoned Reign, p. 283. In addition, Defense Minister Charles Hernu stated in June 1983 that France had already tested a ERW device at Mururoa, and that he was present at the test ("Neutron bomb 'device' explodes at Mururoa," New Scientist, 30 June 1983, p. 925.). As Hernu was present at this test of 08-03-81, this could have been the first ERW test.

114. According to French Embassy (N.Y.), News and Comments, 27 November 1981. Also, neither test in December involved an ERW, according to French Embassy (N.Y.), News and Comments, 10 December 1981.

115. According to DIRCEN, "Dossier no. 1," 12 tests were conducted in 1981, one more than previously thought.

116. Six tests according to DIRCEN, "Dossier no. 1" and DSIR printout; only five according to FOA printout.

117. CEA, Rapport Annuel 1982 (Paris: CEA, 1983), p. 71.

118. AFP, "Essai Nucléaire Français dans le Cadre d'Etudes sur la Bombe a Neutrons," 25 March 1982, stated that the test involved a neutron device of 1-2 kt (as opposed to a prototype warhead), and that this was the sixth such neutron test since the beginning of 1982(?). According to UPI (Paris), "French Atomic Test Reported in Pacific, New York Times, 26 March 1982, the test involved the "trigger" for the ERW.

119. Danielsson, Poisoned Reign, p. 296.

120. According to DSIR printout (includes the two extra tests recently discovered by further review of the Yellowknife seismological records). DIRCEN, "Dossier no. 1," gives seven tests.

121. CEA, Rapport Annuel 1983 (Paris: CEA, 1984), p. 73.

122. This test was detected by Geological Survey of Canada (Yellowknife seismological array), and subsequently confirmed by DSIR. According to Dr. Robert North, Geological Survey of Canada, subsequent analysis of DSIR records revealed a weak T-phase signal, corresponding to yield of <1 kt.

123. This test was detected by Geological Survey of Canada (Yellowknife seismological array), and subsequently confirmed by DSIR. According to Dr. Robert North, Geological Survey of Canada, subsequent analysis of DSIR records revealed a weak T-phase signal, corresponding to yield of <3 kt.

124. CEA, Rapport Annuel 1984 (Paris: CEA, 1985), pp. 73-74.

125. FOA printout. Furthermore, two sources give yield of 70 kt: the New Zealand Prime Minister, quoted in, "France Continues Nuclear Programme," New Scientist, 5 January 1985, p. 6; Greenpeace, "French Nuclear Weapons Testing in the Pacific," press briefing on 4 September 1985, p. 5.

126. CEA, Rapport Annuel 1985 (Paris: CEA, 1986), p. 78. Reuters, "France Plans to Continue A-Tests at Pacific Atoll," Newark Star-Ledger, 10 September 1985, p. 27, also mentions the testing of the ASMP warhead (TN 80/81), and final tests on an ERW. Jim Wolf, "France and NZ Settle Greenpeace Dispute," Jane's Defence Weekly, 19 July 1986, p. 49, states that French agents blew up the Greenpeace vessel Rainbow Warrior in July 1985 in order to prevent disruption of tests involving the development of the TN 71 warhead and a 60 kt warhead for the Hadès missile.

127. According to some sources, this test had the largest yield (at 150 kt) since tests were moved underground; Greenpeace, "French Nuclear Weapons Testing in the Pacific," press briefing on 4 September 1985, p. 5; AFP, "Lange Concern Over Large French Nuclear Explosion Viewed," 10 May 1985.

128. Bertrand Labasse, "L'Enfer Maitrise," TAM, December 1985, p. 22-25.

129. Jacques Isnard, "Force Tranquille," Le Monde, 26 October 1985, p. 12, stated that the HÉRO test was necessary for the "conception of a future tactical nuclear weapon, which is achievable in the next 12-18 months." Bertrand Labasse, "L'Enfer Maitrise," TAM, December 1985, p. 22-25, stated that the HÉRO test was in the "scientific" category of tests, to make an existing warhead lighter, which implies the TN 81, although a warhead for the Hadès is also possible.

130. DSIR printout gives time of 16:01.

TABLE 2: History of French nuclear tests, 1960-1988

Year	No. of tests A	No. of tests UG
1960	3	0
1961	1	1
1962	0	1
1963	0	3
1964	0	3
1965	0	4
1966	6	1
1967	3	0
1968	5	0
1969	0	0
1970	8	0
1971	6	0
1972	3	0
1973	5	0
1974	8	0
1975	0	2
1976	0	4
1977	0	8
1978	0	8
1979	0	9
1980	0	13
1981	0	12
1982	0	6
1983	0	9
1984	0	8
1985	0	8
1986	0	8
1987	0	8
1988	0	8
Total	48 + 124 = **172**	

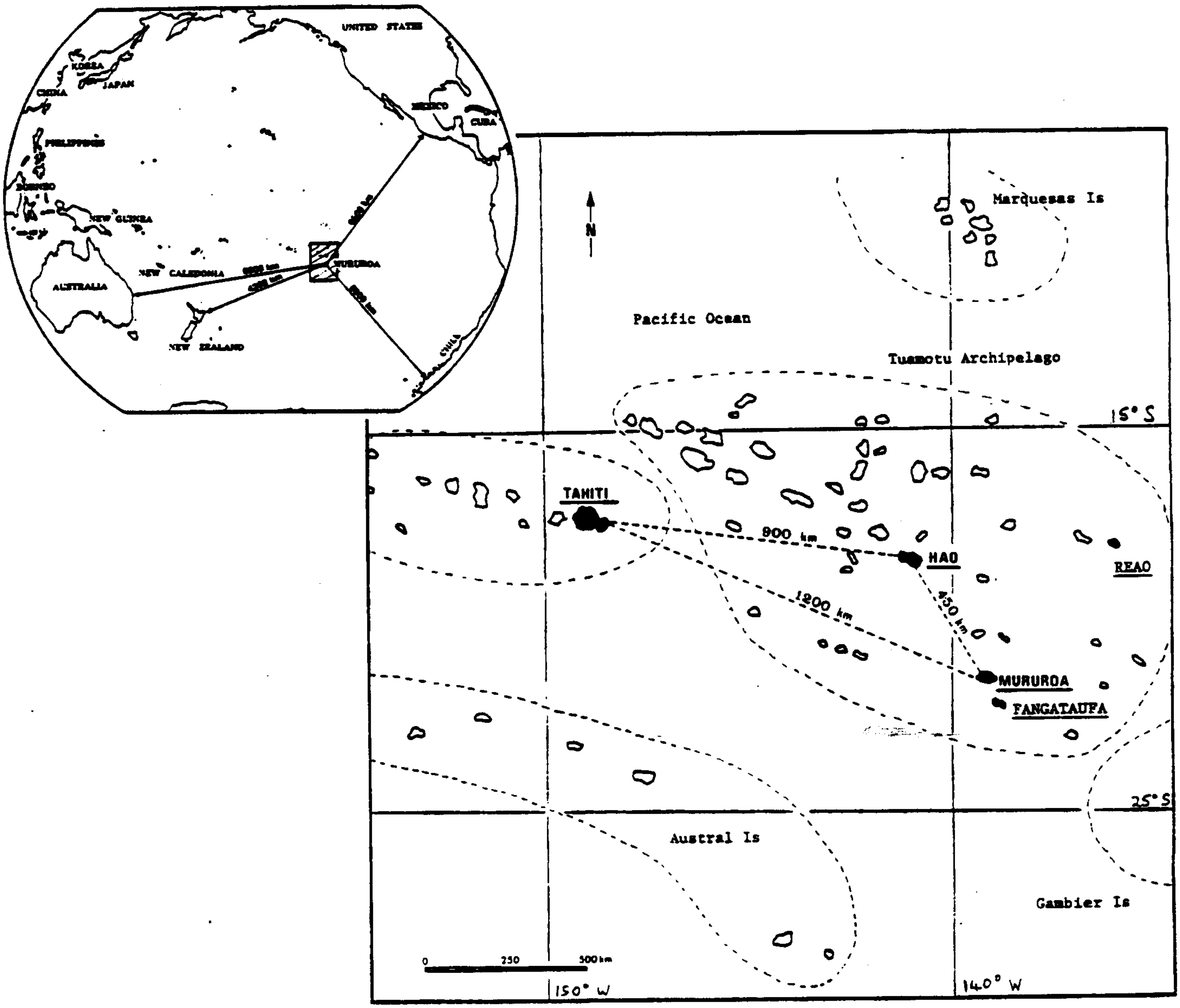
1960-1961: 4 atmospheric tests in Algeria

1961-1966: 13 underground tests in Algeria

1966-1974: 44 atmospheric tests at the Pacific Test Center: 39 over Mururoa, 5 over Fangataufa

1975-1988: 111 underground tests at the Pacific Test Center: 108 at Mururoa, 3 at Fangataufa

Figure 1: Map of the Tuamotu Archipelago



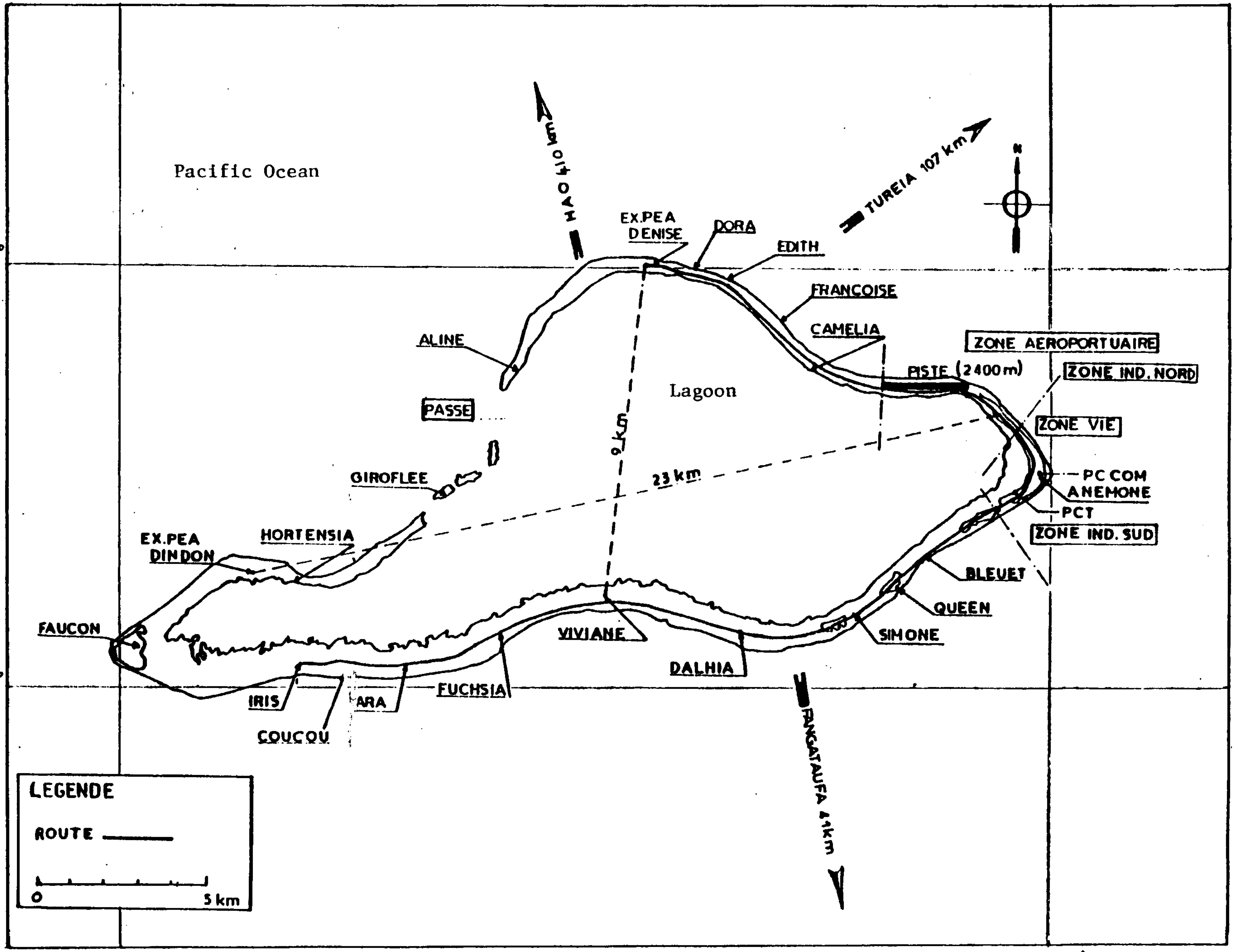


Figure 2: Map of the Mururoa Atoll

Figure 3: Geological cross-sectional diagram of Mururoa Atoll

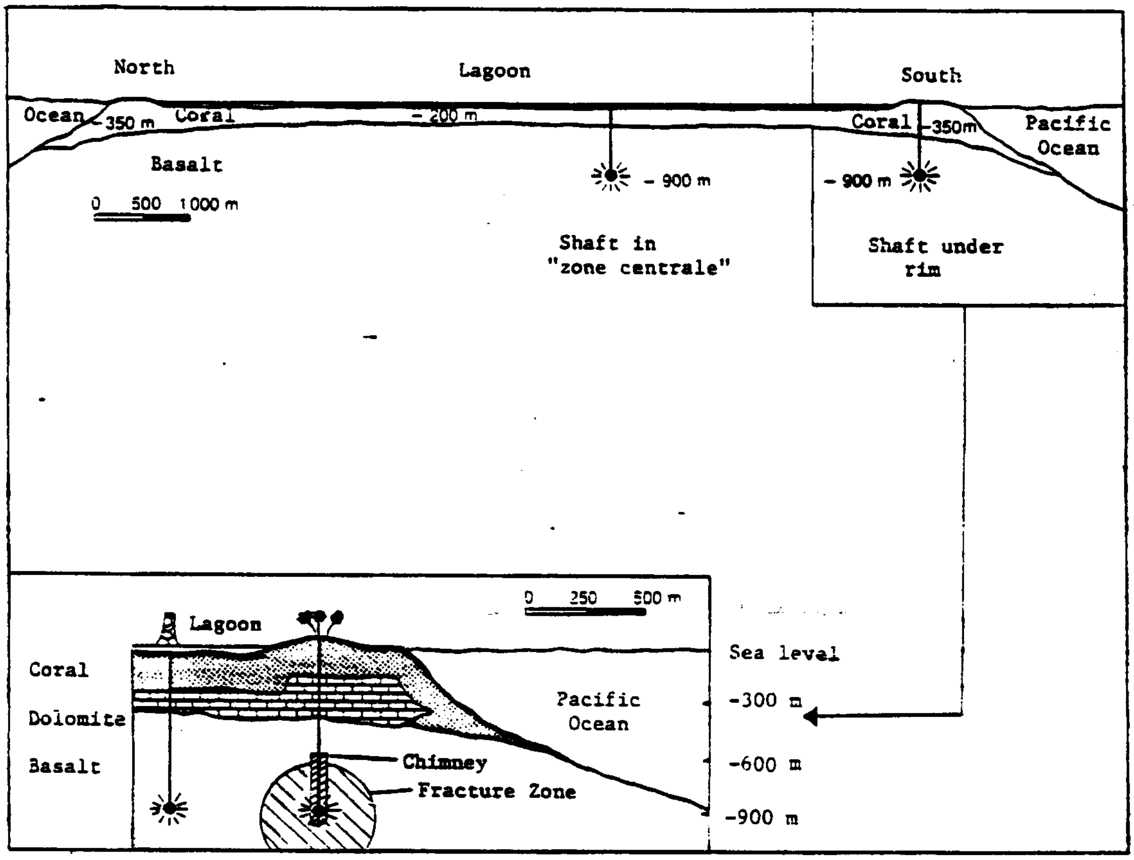
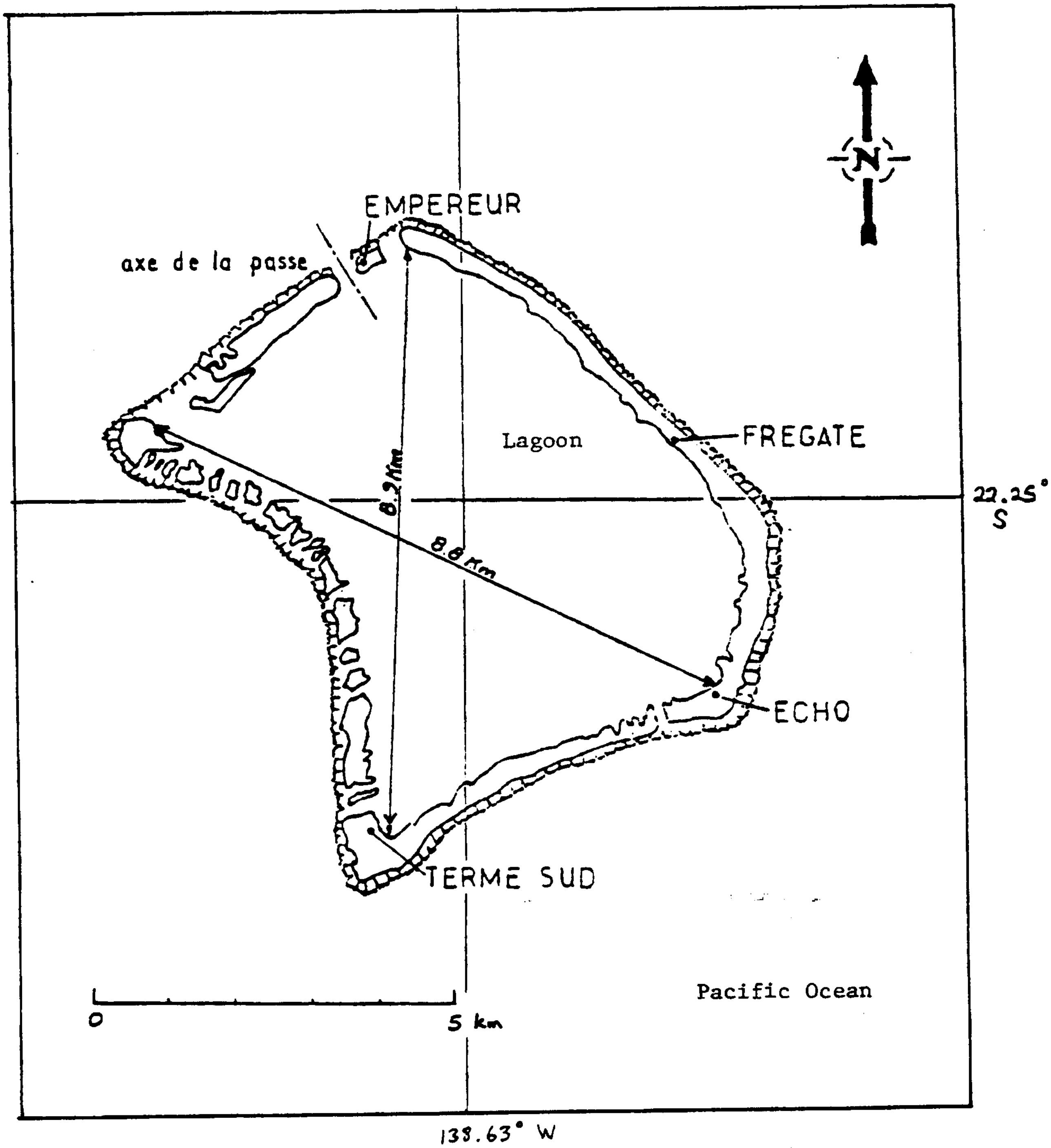


Figure 4: Map of the Fangataufa Atoll



APPENDIX 1: Geography and geology of the French test sites

Sahara Test Site

Reggane Proving Grounds: Four atmospheric tests were conducted at the Reggane Proving Grounds, in what was then French Algeria. While the base Headquarters (0:17 E, 26:42 N) was near Reggane, the detonation sites were some 48 km (at minimum) to the SW, closer to Hammoudia.

In Ecker Proving Grounds: 13 underground tests were conducted in the Taourirt Tan Afella granite intrusive (also called the Hoggar Massif), at In Ecker, which is located about 560 km SE of Reggane, in the southern part of Algeria (5:03 E, 24:03 N).

Pacific Test Site (CEP)

Tuamotu Archipelago: The Tuamotu Archipelago is one of five archipelagoes making up French Polynesia, and is comprised of about 80 Tuamotuan atolls. Located in the extreme SE corner of the Tuamotu Archipelago are two islands that have been used for French nuclear tests, the small uninhabited atolls of Mururoa and Fangataufa (Figure 1). These atolls are located about 1200 km from Tahiti.

These sites, originally chosen because of their isolation, was thought to make them particularly suitable for atmospheric tests. However, both atolls are surrounded to the west, north and east by inhabited islands. In May 1966 the CEP promised to detonate bombs only if when the winds were blowing towards the southern portion of the ocean where there are no islands, in the direction of Antarctica.

Mururoa Atoll: The site of 39 atmospheric and 108 underground tests since 1966, Mururoa is a coral atoll covering an area of about 10 by 30 km, centered on coordinates 138.88 W, 21.83 S (Figure 2). A 200-300 m wide strip of land 50 km long (circumference of atoll) almost totally encircles the lagoon, save for a 4 km wide gap in the reef which connects the lagoon to the Pacific ocean. The average depth of the lagoon is only 30-40 m, with the greatest depth not exceeding 50 m. Mururoa is the visible rim of an extinct underwater volcano, where the outer coral has grown above sea level, enclosing a lagoon. The narrow exposed reef stands only 1 to 2 m above mean sea level.

Nuclear devices are detonated underground at Mururoa in the basalt core of the atoll, at the bottom of a shaft drilled through the surface layers of coral, limestone, and dolomite. Mururoa has a basalt base (Figure 3).

Fangataufa Atoll: The site of five atmospheric and three underground tests since 1966, Fangataufa is roughly 5 by 8 km, and centered on coordinates 138.63 W, 22.25 S (Figure 4). Fangataufa is 41 km SSE of Mururoa. The coral rim rarely exceeds 200 m in width. In many places the sea washes over the low reef. As Fangataufa was a closed atoll, the French Army blasted a 400 m gap in the coral ring, leading to the ocean.

APPENDIX 2: Organization of agencies involved in French nuclear testing[1]

The design and manufacture of the nuclear device to be tested (and associated test instrumentation) is the responsibility of the Military Applications Branch (DAM) of the CEA.

However, the preparation and the support of the tests are assured by the Direction des Centres d'Expérimentations Nucléaires (DIRCEN), which is directly subordinate to the French Ministère de la Défense.

DIRCEN

DIRCEN, created in January 1964, is charged with the conception, the realization (construction), and the working (functioning) of the nuclear testing center (the CEP), as well as the preparation and execution of the tests. DIRCEN is composed of a number of different branches:

- Headquarters located at Villacoublay in France;
- the Groupement Opérationnel des Expérimentations Nucléaires (GOEN), the operational arm of the organization, responsible for conducting the nuclear tests at the site;
- the Direction des Travaux et Services (DTS), based at Villacoublay, responsible for the organization of logistical support at the test site;
- the Service Mixte de Contrôle Biologique (SMCB), responsible for radiological surveillance and safeguards of animals, foodstuffs, and drinking water, near the test site; SMCB is based at Montlhery, with an annex at Mahina, near to Papeete, and a biological control ship, the MARARA, for obtaining all marine samples;
- the Service Mixte de Sécurité Radiologique (SMSR), composed of personnel from the Army and the CEA, responsible for the radiological security of the tests (i.e. avoid contamination), and the protection of the population from radioactivity; SMSR is based at Montlhery, and Mururoa; and,
- the Centre d'Expérimentations du Pacifique (CEP), the Pacific test site, created in 1962.

The organization of the CEP

La Base Interarmées des Sites (BIA): comprising the atolls of Mururoa and Fangataufa, and the peripheral stations on the atolls of Tureia, Tematangi, and

[1] DIRCEN, "Dossier no. 1," sections 1/11, 2/11, 1/21, and 2/21.

Reao. BIA is responsible for logistical support to CEA, preparation of tests, ensuring security of the installations. A maximum of 3600 people (military personnel, scientists, and engineers) are present at BIA during a testing period, with minimum of 3000 otherwise (of which about 1500 are military).

Both Fangataufa and Mururoa have wharfs and airstrips originally built by the military. Mururoa has a lagoon deep enough to safely harbor large ships.

La Base Interarmées de Hao: In the 1960s, Hao atoll served as a rear base for assembling the nuclear devices to be tested, which were flown from France, via refuelling in Martinique, thus avoided altogether the densely populated (and highly critical) Tahiti. Hao is a bigger atoll than Mururoa, and located 410 km NW of Mururoa. At present Hao atoll houses 400 people, of which 270 are military (Army and Air Force). Built by the military, it has one of the longest runways in the South Pacific, together with a large number of storehouses and workshops. Following the construction of a runway on Mururoa, the nuclear device assembly facility (Centre Technique CEA/DAM) at Hao was deactivated, and transferred to Mururoa.

Elements of the three services located at Tahiti: About 1100 personnel are located at Papeete, Faaa, Arue, and Mahina. Tahiti also serves as a rear base for R&R.

At the various sites of the CEP, the Army has about 1500 personnel,[2] the Navy about 850 (of which 250 are embarked on 31 vessels),[3] and the Air Force 550.[4]

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[2] The Armée de Terre has four main units: the 5° Régiment Étranger, HQ at Mururoa; the 57° Bataillon de Commandement et de Soutien du Pacifique, HQ at Papeete; the 815° Bataillon de Transmissions, Terre, HQ at Papeete; the Direction de l'Infrastructure et du Matériel en Polynésie, HQ at Papeete.

[3] The Navy personnel are distributed between 31 boats; the ports of Papeete and Mururoa; the Atelier Militaire de la Flotte at Mururoa; and at the Commissariat de la Marine at Papeete.

[4] Armée de l'Air personnel are located at Base Aérienne (BA) 190 at Faaa, BA 185 at Hao, BA 195 at Mururoa; and l'Escadron de Transport Outre-Mer no. 82 at Faaa and Mururoa.

FRENCH ACRONYMS

AN (Arme Nucléaire): atomic weapon, i.e. a fission weapon, such as AN 22, 51, or 52. See TN, thermonuclear weapon.

APEX (Applications des Explosions): a series of underground nuclear tests in Algeria conducted by the CEA; experiments in the peaceful uses of nuclear explosives.

ASMP (Air-Sol-Moyenne-Portée): medium-range air-to-ground nuclear missile (TN 80/81 warhead). Deployed on the Mirage IVP, Mirage 2000N, and Super Etendard aircraft.

CEA (Commissariat à l'Energie Atomique): the French Atomic Energy Commission, responsible for all aspects of the French nuclear warhead program, including warhead design, manufacture, and nuclear materials production. See DAM.

CEB (Centre d'Études du Bouchet): Bouchet Research Center, an annex of the ETCA; nuclear weapons effects simulation.

CEG (Centre d'Études de Gramat): Gramat Research Center, an annex of the ETCA; nuclear weapons effects simulation.

CEL (Centre d'Essais des Landes): Landes Test Center, located at Biscarrosse; ballistic missile flight test range.

CEP (Centre d'Expérimentations du Pacifique): the Pacific Test Site; see Appendix 1 and 2.

CESTA (Centre d'Études Scientifiques et Techniques d'Aquitaine): Center of Scientific and Technical Studies of Aquitaine, one of the R&D centers of the Military Applications Branch of the CEA.

CFDT (Conféderation Française Democratique du Travail Union): French trade union representing technicians employed at Mururoa.

DAM (Direction des Applications Militaires): the Military Applications Branch of the CEA, specifically responsible for the design and manufacture of all French nuclear device and weapons, and associated test instrumentation.

DIRCEN (Direction des Centres d'Expérimentations Nucléaires): See CEP, and Appendix 2 for further details.

ETCA (Établissement Technique Central de l'Armement): the Central Technical Establishment for Armament; nuclear weapons effects simulation at Bouchet (CEB) and Gramat (CEG).

TN (Thermonucléaire): thermonuclear warhead, as in the TN 61, 70, 70, 80, 81 etc. See AN.

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Nuclear Notebook, <u>Bulletin of the Atomic Scientists</u> (monthly).

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