[redacted]

HUNTING - BRAE

APPROVED DOSIMETRY SERVICES

(HEALTH EFFECTS)

Document Reference No: AWE/HPRK/C/REP/HE/98/01

Document Category: C

Issue 1 March 1998

AIRCRAFT DECONTAMINATION AT THE UK ATMOSPHERIC NUCLEAR TRIALS

Distribution List: [redacted]

Prepared by [redacted] Date 12/5/98

Approved by Date 13/5/98

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1. AIM

1. 1 This is intended as a briefing note summarising the documentary record that exists at AWE at the date of writing on the involvement of the RAF in air sampling, active aircraft handling and decontamination in the UK atmospheric nuclear trials and associated experimental programmes in Australia and the Pacific, between 1952 and 1987. It is believed that this documentation is largely complete and representative, though there may be items that have not been seen by the compilers (such as, for instance, RAF Officers' Flying Log Books, which are personal property).

2. NOTE ON SOURCES

2.1 This note has been compiled from a mass of documentation held by the Approved Dosimetry Services (Health Effects), Environmental and Radiation Protection Division, AWE Aldermaston. Some are formal AWE Reports, some are in the form of memoranda and correspondence, and some are rough manuscripts prepared shortly after the events to which they refer. Use has also been made of personal communication with those involved at the time, both AWE staff and Service Officers. The reference list identifies the most significant items. (Only documents Unclassified at the time of writing are listed). While every effort has been made to transcribe information accurately from original sources, those sources should always be used to confirm any detail in this document.

2.2 It should be noted that the Atomic Weapons Research Establishment Aldermaston, part of the Ministry of Supply, was the civilian authority on nuclear weapons design during the period of interest and remains so today. This establishment later transferred to the United Kingdom Atomic Energy Authority and then the Ministry of Defence. In 1987 it was reorganised as the Atomic Weapons Establishment, incorporating other sites. The historic term AWRE will be found in all the contemporary reference documents; the current term AWE is used in this document.

3. CHRONOLOGY OF UK ATMOSPHERIC NUCLEAR TRIALS

3.1 The decision to develop nuclear weapons for the UK Armed Forces was taken by the GEN 163 Committee on 8 January 1947. An account of the political background is given in **References 1 and 9**. The RAF was the customer for the first weapon, the 10,000 lb bomb, codenamed BLUE DANUBE. It was designed to be carried by V-bombers (see **References 12 and 16**). RAF officers were intimately involved with the design of this weapon, the aircraft interfaces and ground support equipment, and in the development of delivery techniques. A group was set up at Fort Halstead under the name High Explosive Research to oversee the programme. Later a dedicated establishment was set up at Aldermaston. This opened on 1 April 1950 under the name Atomic Weapons Research Establishment.

3.2 It soon became apparent that existing theory was inadequate to guarantee the performance of service weapons. It therefore became necessary to mount a live trial. A search was carried out for a suitable site, under the control of the UK but remote from human habitation or trade routes and with a suitable climate.

3.3 The site finally chosen for the first UK nuclear trial, Operation HURRICANE, was the Monte Bello Islands, off the coast of West Australia. This was primarily a Naval operation with a Royal Navy Task Force Commander, though there were elements of the other Services and a party of civilian scientists, engineers and technicians. RAF officers escorted classified components to the trial site and assisted with the assembly of the trial device, which was essentially the centre section of a service 10,000 lb bomb. This was mounted on a stillage in the wardroom (just below the waterline) of the redundant River Class frigate HMS Plym (F271), moored off Main Beach, Trimouille Island. The first British nuclear detonation took place at six seconds before 0130 hrs GMT on 3 October 1952 and gave a yield of 25 kilotons, very close to that predicted. The trial provided sufficient confidence in the design to permit introduction into service of UK nuclear weapons. Unclassified accounts of Operation HURRICANE are given in **References 4, 5, 29 and 43**.

3.4 Development problems led to a requirement for further trials in 1953. The practical difficulties involved in mounting a seaborne operation led to a search for a land site. One was eventually found near Emu Claypan in the Outback of South Australia, adjacent to the recently commissioned Long Range Weapons Establishment at Woomera. The site was remote. Although there was land access via rough tracks, most supplies had to be flown in to a temporary airstrip on the claypan (although even this became unusable in wet weather). Under the codename Operation TOTEM, two trials devices were fired on 31-metre towers on 14 and 26 October 1953, with yields of 10 and 8 kilotons respectively. This operation was entirely successful. A general account of the operation is given in **Reference 3**.

3.5 By 1954 it had been realised that there would be a continuing requirement to develop new types of nuclear warhead. Also, studies of nuclear battlefield scenarios indicated that a wide range of military equipment could be affected by nuclear weapon effects in the event of war and had to be designed accordingly. This gave rise to a requirement to expose such equipment to the effects of nuclear detonations under experimental conditions (target response tests). A search was instituted for a suitable site that could be developed as an outstation of AWRE Aldermaston, with permanent facilities. An area was identified in the Outback of South Australia, south of Emu Claypan and north of Watson on the transcontinental railway. The site was developed in cooperation with the Australian Government as the Maralinga Range. The site incorporated a village for the accommodation of trials personnel, a fully equipped airfield capable of handling heavy transport and bomber aircraft, and technical areas for scientific and engineering work. The firing sites were in the Forward Area, open uninhabited country to the north of the village. The range is described in **References 24, 25 and 28** Part 1.

3.6 On 6 April 1955 a decision was taken by the Chiefs of Staff that there was a requirement for nuclear warheads of significantly greater yield than hitherto. It was therefore necessary to carry out trials to study the design problems involved. It was not possible to do this at Maralinga in 1956, as the trials would interfere with the construction of the range facilities. Accordingly, a seaborne operation under the codename MOSAIC was mounted to carry out a trial at the Monte Bello Islands. Two trials devices were fired on 31 metre towers, the first on Trimouille Island on 16 May 1956 with a yield of 15 kilotons and the second on Alpha Island on 19 June 1956 with a yield of 60 kilotons. An account of the Operation is given in **Reference 36**.

3.7 In 1956 the Maralinga Range came into use for Operation BUFFALO, during which four nuclear devices were detonated as part of a continuing experimental programme. In addition, the

opportunity was taken to expose a variety of military equipment and structures to the effects of the detonations in order to gather data on nuclear weapon effects. The first device was fired at One Tree on 27 September on a 31-metre tower with a yield of 15 kilotons. The second was fired at Marcoo on 4 October, in a concrete emplacement with the centre of the device at ground level. Yield was 1.5 kilotons and a substantial crater was produced. The third detonation was the first live air drop of a service nuclear weapon by a Valiant aircraft of No 49 Squadron RAF. Detonation took place at an altitude of 150 metres over Kite. Yield was 3 kilotons; the warhead had been modified to produce this low yield as a precaution against excessive fallout in the event that the radar fuses failed and detonation occurred at surface impact. The fourth device was fired at Breakaway on 21 October on a 31-metre tower with a yield of 10 kilotons.

3.8 During Operation BUFFALO an Indoctrinee Force of officers from the Armed Services of the UK and Commonwealth countries took part. They assisted in setting up target response items, witnessed detonations and inspected the Forward Area after detonation (see **Reference 23**).

3.9 The decision was taken on 27 July 1954 to develop high-yield warheads for bombs and guided missiles. By 1956 the program had progressed to the point where a major trial was necessary to gather data on which design options could be based. It was not possible to carry out such a trial at Maralinga, as the yields would have been greater than those envisaged when the agreement to set up the Range was made with the Australian Government. The logistical difficulties in operating at the Monte Bello Islands stimulated a search for a more suitable base. After a search directed by [redacted], one was eventually found at Christmas Island in the Line Islands in the Central Pacific. (Then a UK possession, it is now known as Kiritimati and is part of the Republic of Kiribati.) A reconnaissance was carried out using RAF Shackletons under the codename 'Cook's Tour'. Christmas Island was small and isolated with few local inhabitants. The island is described in **Reference 28** Part 2. An intensive programme of construction was instituted. The existing wartime airfield was rebuilt to handle heavy bomber and transport aircraft and a port was constructed, with scientific and technical facilities and accommodation for a support force of about 2,000.

3.10 Operation GRAPPLE took place in the Spring of 1957. Experimental nuclear devices fitted into BLUE DANUBE aerodynamic vehicles were dropped from Valiant aircraft of No 49 Squadron RAF. The planned surface zero was a few kilometres to the south of the small, uninhabited Malden Island, 700 kilometres to the south south-east of Christmas Island. The operation was supported by a naval task force. Instrumentation was set up on Malden Island prior to the detonation, after which all personnel were evacuated by helicopter to the ships, which then stood off at a safe distance upwind of planned surface zero. The detonations took place as planned over the sea off the coast of Malden island. Detonation altitude was planned to eliminate the risk of fallout while also minimising risk to the dropping aircraft. The limiting factor on aircraft hazard was the structural damage from thermal radiation. Specially modified high-reflectance finishes were applied to the Valiants to minimise heat absorption, stencil markings were toned down and great attention was paid to eliminating surface features that could absorb heat; e.g. black rubber seals were replaced by white silicon rubber alternatives. A special escape manoeuvre was evolved to place the aircraft as far away as possible from the device at time of detonation, with tail towards it. This required very precise airmanship, as the aircraft had to perform a tight turn near its effective ceiling, where the margin between maximum speed and stalling speed was small (and reduced during the manoeuvre, as stalling speed increases in a turn). A sensitive accelerometer was fitted to help judge the turn. Target markers were laid out on Malden island and bombing was by visual offset. Radar tracking was available to enable the drops to take place even if the target markers were obscured by cloud, though in the event this was not necessary. Many rehearsals were carried out using high explosive and inert telemetered bombs before the live trial. Originally it had been intended to use an instrumented range at Christmas Island for these

conditions were safe to permit the landing of personnel to recover instrumentation and records. Accounts of this Operation are given in **References 10, 14** and **16** and technical details in **References 42** and **45**.

3.11 Round 1 of Operation GRAPPLE was the experimental device SHORT GRANITE, dropped on 15 May 1957. Detonation took place at an altitude of 2200 metres and yield was 300 kilotons. Round 2 was the device ORANGE HERALD, dropped on 31 May. Detonation took place at an altitude of 2400 metres and yield was 0.7 megatons. Round 3 was the device PURPLE GRANITE, dropped on 19 June. Detonation took place at an altitude of 2400 metres and yield was 200 kilotons.

3.12 The experimental programme at Maralinga continued in 1957 with Operation ANTLER. Round 1 was detonated on 14 September on a 31 metre tower at Tadje. Yield was 1 kiloton. Round 2 was detonated on 25 September on a 31-metre tower at Biak. Yield was 6 kilotons. The third round was suspended from an array of balloons at an altitude of 300 metres. Yield was 25 kilotons. This form of suspension was designed to give a higher detonation altitude, and consequent lower risk of fallout, than was practicable with a tower. At the same time it permitted greater precision of alignment with instrumentation than was possible with an airdrop. Considerable experimental work by ML Aviation Ltd was necessary to develop a safe and reliable method of suspension. The developed rig used at ANTLER (and later at GRAPPLE Z) consisted of two, three or four 84,000 cubic foot ballonet type balloons moored by a tripod of cables. The trial device and associated instrumentation was mounted in cage suspended from the apex of the tripod, with flexible braces to control swing and twist. The exact arrangement differed slightly between rounds. The principles of design and operation are set out in **Reference 40**.

3.13 Operation ANTLER comprised the last nuclear detonations to take place in Australia. The Maralinga Range continued in use for several series of experiments known as the MINOR TRIALS. The widespread deployment of service nuclear weapons in the UK and Europe stimulated requirement for information on their likely behaviour in accidents such as aircraft crashes and fires. The MINOR TRIALS were a series of experiments to gather data on the behaviour of fissile materials in fires and nuclear assemblies in fires and accidental detonations. Many of these involved explosive disruption of assemblies containing radioactive materials (including plutonium) and resulted in significant long-term contamination of the Range area. Indeed, virtually all the radioactive hazard remaining at Maralinga at the time of writing is due to the MINOR TRIALS. For a summary of trial activities in Australia see **References 1, 2, 37 and 39**.

3.14 There was a continuing requirement for high-yield trials at Christmas Island. The logistic difficulties with a target 700 kilometres from the base, and the need to refit some of the specially equipped ships used at Operation GRAPPLE, led to examination of the possibility of carrying out the trials at Christmas Island itself. This would permit considerable economy of effort and eliminate the hazard to aircrew of flying long distances over the open ocean. Theoretical studies predicted that detonations of up to 3 megatons off the south-east point of the island would pose no hazard to personnel in the open who were no closer than the airfield (about 35 kilometres), provided that they did not look towards the fireball and covered all exposed skin.

3.15 Operation GRAPPLE X consisted of one detonation, on 8 November 1957. The trial device, in a BLUE DANUBE aerodynamic vehicle, was dropped from a Valiant of No 49 Squadron RAF over the sea off the south-east tip of Christmas Island. Detonation took place at an altitude of 2200 metres and yield was 1.8 megatons. This was the first megaton detonation by the UK. As planned, there was no fallout on Christmas Island; the prevailing north-easterly Trade Winds took the cloud away from the inhabited areas. There was some minor blast damage to buildings but there were no injuries to personnel.

3.16 Operation GRAPPLE Y consisted of one detonation, on 8 April 1958. The dropping arrangements were the same as for GRAPPLE X. The detonation took place at an altitude of 2500 metres and the yield was 3 megatons, the largest of any UK trial.

3.17 Operation GRAPPLE Z, the last UK atmospheric nuclear trial, took place in the autumn of 1958. Round 1 (PENNANT) was suspended from a balloon array over a flying site at the south-east tip of the island. Detonation took place on 22 August at an altitude of 450 metres. Yield was 24 kilotons. Rounds 2 and 3 were dropped by Valiants in a similar manner to GRAPPLE X and Y. Round 2 (FLAGPOLE) was dropped on 2 September. Detonation took place at an altitude of 2800 metres and yield was 1 megaton. Round 3 (HALLIARD) was dropped on 11 September. Detonation took place at an altitude of 2600 metres and yield was 0.8 megaton. Round 4 (BURGEE) was suspended from a balloon array in a similar manner to Round 1. Detonation took place at an altitude of 450 metres and yield was 25 kilotons.

3.18 Following Operation GRAPPLE Z the Christmas Island base was reduced to a care-and-maintenance basis. Further operations (GRAPPLE M and O) were planned but abandoned following the Moratorium on atmospheric nuclear testing which commenced on 31 October 1958. HQ Task Force GRAPPLE was disbanded on 3 June 1960.

3.19 Operation GRAPPLE Z was the last UK atmospheric nuclear trial. All subsequent UK nuclear trials have been underground at the US National Test Site in the Nevada desert. The first UK UGT was Operation PAMPAS on 1 March 1962.

3.20 In 1962, the US staged part of Operation DOMINIC at Christmas Island, with the agreement of HMG. A total of 24 detonations (all high airbursts) took place in the Christmas Island area between April and July 1962. The surface zero markers were barges some miles off the south-east point of the island. The US forces based at Christmas Island were mainly for command and control, though a flight of B57's (equivalent to the Canberra) were based there for air sampling duties. Trial devices were dropped from B52's; device assembly and loading took place at NAS Barber's Point, Oahu in Hawaii. UK participation in Operation DOMINIC was codenamed Operation BRIGADOON. Civilians were based at Christmas Island to advise on safety and aircraft decontamination. They served on the Safety Committee, which had power of veto over any detonation. An RAF element was based at the airfield to provide services to US and RAF aircraft. See **References 32 and 44** for details of the detonations at Operation DOMINIC.

3.21 It should be stressed that in no case did any hazard arise from unexpectedly high yield at a UK atmospheric nuclear trial. In all cases where devices were air dropped or balloon supported, the detonation took place at, or very close to, the altitude intended. In no case did any hazard arise from a detonation taking place at other than the altitude assumed in the planning process.

3.22 Fallout from the 15 Megaton BRAVO detonation of the US Operation CASTLE at Bikini atoll on 28 February 1954 contaminated a Japanese fishing vessel and subjected its crew to significant radiation doses; one later died. The series also caused significant contamination of the Marshall Islands and significant radiation doses to the indigenous inhabitants, who were later evacuated. Resulting publicity gave impetus to a world-wide public reaction against nuclear weapons and their testing. On October 31 1958 the US entered into a nuclear testing Moratorium with the understanding that the then USSR would also refrain from conducting nuclear tests. The Moratorium was broken by the USSR with a trial on 1 September 1961. The USA followed on September 15 1961 with the ANTLER detonation of Operation NOUGAT at the Nevada Test site and later Operation DOMINIC, a series of detonations at Christmas Island and elsewhere in the Pacific, including FRIGATE BIRD,

ballistic missile with a live nuclear warhead. On 5 August 1963, the US and the then USSR signed the Limited Test Ban Treaty which effectively prohibited testing of nuclear devices in the atmosphere. All subsequent US and UK nuclear detonations have been underground trials (UGT's). The French continued atmospheric nuclear trials until 1972 when they to moved to UGT's in the Pacific. The UK UGT's have all been conducted at the US Department of Energy Test Site in Nevada by arrangement with the US authorities.

3.23 The Christmas Island base was closed down in 1964, all valuable items being recovered and waste dumped in the sea. The island was then surveyed. A certificate was issued on behalf of the Director AWRE stating that "As a result of the decontamination and radiological survey undertaken by this Establishment in June, 1964, it is certified that no radiological hazard remains on Christmas Island as a consequence of the tests undertaken in that area in the period 1957 - 1962". A survey in 1981 by the New Zealand authorities (**Reference 38**) on behalf of the Government of Kiribati confirmed that no radioactive hazard existed.

3.24 The Maralinga Range was closed down in 1967, all valuable items being recovered and waste buried. Efforts were made to remove any remaining hazards and restore the site to its original state. Between February and March 1979 some plutonium-contaminated waste was exhumed and repatriated to the UK. Following the Australian Royal Commission into the conduct of UK nuclear trials in Australia (**Reference 37**), further surveys and investigations were carried out. Between May and July 1987 an aerial survey of radioactive contamination was carried out. An RAF detachment flew Wessex HC2 helicopters equipped with sensitive radiation monitors provided and operated by a US contractor, with support from AWRE civilians. Details are given in **Reference 33**. Discussions have taken place between the UK and Australian Governments and further remedial work is under consideration.

3.25 A summary of the UK atmospheric nuclear trials programmes is given at **Appendix A.**

3.26 A summary of the involvement of major RAF units with the UK atmospheric nuclear trials is given at **Appendix B.**

3.27 The principal RAF aircraft involved in air sampling, reconnaissance and related activities at the nuclear trials are listed at **Appendix C**. The (admittedly subjective) criterion for listing is that an aircraft was airborne at the time of the detonation or shortly afterwards, and sufficiently close to the detonation that the risk of being affected by some effect of that detonation was not negligible. This information has been drawn mainly from the contemporary RAF Operations Record Books (**Reference 45**), cross-checked with other references. There are gaps in the list; for instance, it has not been possible to trace the serial numbers of the Canberras in the air at the time of Operation GRAPPLE X. Wherever possible, individual aircrew are identified by name, rank and service number. There are a few cases where full identification is not possible, and some where the name appears never to have been recorded (as at the GRAPPLE series, where Shackletons are simply noted as carrying a number of passengers). There are also instances where the copy of the Operations Record Book held in the Public Records Office is incomplete.

3.28 The fate of ex-trials aircraft that are known to have been contaminated and could be traced at the time of writing is detailed in **Appendix D**. There is no evidence that any ex-trials aircraft ever presented a hazard to persons who might come into contact with them after health controls on the aircraft were relaxed.

4. AIR SAMPLING AT UK ATMOSPHERIC NUCLEAR TRIALS

4.1 Limited air sampling of radioactivity took place at Operation HURRICANE in 1952 (see **Reference 20**). Low level aerial surveys of ground contamination were carried out on the morning of the day after firing by two RAAF Dakotas, each flying at 500 feet and equipped with sensitive gamma monitors. Sampling at a range of approximately 500 miles from the detonation was carried out by 7 RAAF Lincoln aircraft based at Broome. Sampling at a range of 2000 miles was carried out by 7 more Lincolns from Garbutt near Townsville. Long range sampling (3500 miles plus) was carried out by 2 Bristol Freighters and one Douglas DC3 of the RNZAF based at Whenuapai, North Island, New Zealand. All aircraft were fitted with filters in carriers designed by AERE Harwell. The primary purpose was to confirm the predictions that the radioactive cloud would be carried away from the Australian mainland, and to demonstrate that no hazard had been caused to the civil population, though in the event limited data on isotopic ratios were also obtained.

4.2 It was realised at this time that a sample of the fission products soon after detonation would provide very valuable data to the weapon designers. The relatively crude means of estimating total yield at Operation HURRICANE (rate of fireball growth, prompt radiation output, blast effects etc) provided valuable data but little insight into the functioning of the device. In principle, counting the activities of fission product isotopes present in the sample can give an estimate of the fissions that have taken place. Counting the activities of fissile isotopes present can give a scaling factor to the device. It is therefore in principle possible to estimate the efficiency of the device in terms of fission. The process became much more complex when fusion also occurred in the device but at the same time it is more necessary, as there were more reactions involved and total yield measurements were of little help. As weapon designers were required to produce of warheads of differing yields the requirement to develop techniques of sampling the radioactive cloud became ever more urgent.

4.3 It could be shown that the requirement was very demanding. It would be necessary for the aircraft to enter the radioactive cloud at a time when the external dose rates were of the order of Sieverts per hour, so to stay for too long could be life-threatening to the aircrew. At the same time it was essential to stay in long enough to capture a sample of particulates and gases that would be adequate for the radiochemists to assay to within the limits of accuracy necessary to provide the information needed by the weapon designers. The aircraft also needed to be fast, manoeuvrable and robust enough to withstand the intense turbulence within the rapidly rising cloud.

4.4 Rocket sampling was attempted at Operations HURRICANE, TOTEM and BUFFALO. Standard 3" anti-aircraft rockets were fitted with 29 lb heads modified to carry filters and set up in banks so that they could be fired through the radioactive cloud. While some data were obtained, the method was clearly unsatisfactory. Since the rocket banks had to be set up some hours before firing, last-minute wind changes could make it impossible to aim them so that they passed through the centre of the cloud, unless they were set up so close to the point of detonation that they ran a serious risk of blast damage. Furthermore, it was not easy to recover them afterwards; not all those fired at Monte Bello were subsequently located. All rockets fired at Maralinga and Emu were eventually recovered, though some were deeply buried. In addition, their effective ceiling of 6,000 feet limited them to use in low-kiloton trials only.

4.5 The Lincoln aircraft used at Operation HURRICANE were obviously unsuitable to the task as they were unpressurised, so any suspended particulate radioactivity encountered could easily penetrate the crew compartment, which was then very difficult to decontaminate. The engines also proved to be prone to picking up contamination which was difficult to remove. The aircraft were also slow. The choice fell on the English Electric Canberra aircraft, a twin-jet bomber which was then

entering service. It was fast, manoeuvrable, had a pressurised crew compartment and a smooth surface finish which promised to be easy to decontaminate. The engines were axial-flow types which offered few contamination traps.

4.6 Under the designation Operation HOT BOX, a new Canberra B2 was prepared for Operation TOTEM in 1953. Details are given in **References 18 and 19** and a non-technical account in **Reference 13**. The operational requirement was to obtain information on the following:

a) Behaviour of aircraft and components in the immediate vicinity of a nuclear explosion, including exposure to the blast wave and subsequent cloud turbulence;

b) The effects of intense radiation fields on the electrical systems of the aircraft;

c) The amount of resulting contamination on the aircraft and subsequent ease of decontamination and assessment of risk to those engaged in decontamination procedures.

4.7 Some consideration was given to using an unmanned drone aircraft, but in view of the importance of the data to be collected it was decided that the use of a Canberra was justified if manned by a specially trained and qualified crew.

4.8 As one aircraft would be inadequate to carry out all the necessary air sampling tasks, recourse was made to a similar organisation to that used for Operation HURRICANE. At a range of 400 miles, sampling was carried out by 6 RAAF Lincolns from Broome. At a range of 1200 miles, sampling was carried out by 6 more Lincolns based at Richmond, near Sydney. Long range (3000 miles plus) sampling was carried out by RNZAF aircraft, 3 Bristol Freighters from Whenuapai and 3 Mustangs from South Island. All aircraft carried the AERE type filters and carriers; the Lincolns in addition carried Type 1021 detectors to enable them to track the clouds.

4.9 The Canberra B2 at Operation TOTEM was fitted with the venturi type AERE filter carriers as fitted to the Lincolns; in addition it carried 9" cube cellulose acetate Porton type filters in a modified wing tip tank and moving strip type filters in the fuselage. A special clear high speed finish was applied to minimise surface contamination. The pilot was [redacted] (HQ Bomber Command) who had been trained to fly a Canberra specifically for this Operation. The navigator was [redacted] from HQ Bomber Command and the Radiological Observer was [redacted], a Consultant Radiobiologist from the RAF Medical Service. All carried film badges as well as direct-reading quartz fibre electroscope (QFE) type dosemeters. In addition, fixed direct-reading monitors were mounted in the aircraft. A procedure was established whereby the direct reading instruments were continuously monitored while the aircraft was in the cloud; a steep dive escape manoeuvre was to be initiated immediately a pre-planned limit was reached. In the event this was not necessary.

4.10 It had originally been planned to operate the Canberra from Emu Field, but in the event the runway surface there was judged adequate only for an emergency landing and the flight was based at Woomera.

4.11 Following the detonation on 14 October 1953, cloud penetration were made at 6 and 9 minutes post-detonation. Turbulence was considerable. Dose rates peaked at 400r/hr (4 Sv/hr) below the cloud. No detectable radioactivity was found in the cockpit, though some personal contamination occurred when exiting the aircraft after landing.

4.12 The data collected during the first sampling flight at Operation TOTEM were such that the requirement to carry out a further sortie following the second detonation on 26 October was cancelled, even though the aircrew were willing to carry it out.

4.13 It was apparent from experience at Operation TOTEM that air sampling using Canberras was entirely feasible and that valuable data could be obtained while incurring radiation doses to the aircrew that were within the contemporary safety guidelines. In addition, the aircraft had the ability to remain stable at extreme altitudes when carrying external filters. The only alternative seemed to be the Jindivik drone; this had the disadvantage of a very limited endurance (one hour as against the Canberra's six hours). Its only advantage was freedom from worry about radiation safety for the crew. It was felt that with adequate training and supervision from the ground, doses to a Canberra crew could be kept within reasonable limits in all foreseeable operations. The Canberra thus became the standard air sampling aircraft for the remainder of the UK atmospheric nuclear trials programmes. It was also used, in the Martin B-57 licence-built version, by the US Air Force in similar roles (e.g. at Operation DOMINIC, see **Reference 30**). No. 76 Squadron RAF became the designated air-sampling unit for the UK nuclear trials. Their first task was sampling in support of Operations MOSAIC in the Monte Bello Islands in September and October 1957 and BUFFALO at Maralinga. At the latter, the Canberras were supplemented by Varsities and Whirlwinds which carried out low-level close-in fallout surveys with sensitive gamma monitors. Following this, 76 Squadron moved to Christmas Island for Operation GRAPPLE in the spring of 1957.

4.14 Equipment fitted to air sampling Canberras was of three types;

a) Ducts for sampling particulates

b) Gas storage systems for sampling radioactive noble gases

c) 'Musical Tom Cat', a system for condensing out water from a large volume of air.

4.15 Up to and including Operation MOSAIC, the technique was to make a single pass through the cloud, according to a plan fixed well in advance. This was proved to be unsatisfactory. The method later preferred was for a controller on the ground to direct the aircraft, observed with binoculars, in the appropriate direction. At the Australian trials, it proved particularly difficult to see the radioactive clouds from the air against a background of desert, especially if they were interspersed among cumulus. The ground observer could watch the cloud developing and keep track of it. He also monitored the doses received by the aircrew.

4.16 Since the activity from the detonation was spread through many cubic kilometres of air, this volume had to be swept repeatedly by the aircraft if a representative sample was required. This was not possible at short times post-detonation, as the doses to the aircrew would have been unacceptable. It was shown early in the trials series that dose rate was fairly independent of the size of the cloud and proportional directly to the yield of the device and to the time from burst to the power (-1.2). About 20 minutes post-detonation was the earliest time that penetration by manned aircraft was considered. Delaying entry until 2-3 hours for a kiloton detonation enabled repeated penetrations to be made over a period of 20-30 minutes with much improved sampling efficiency.

4.17 The clouds from kiloton detonations reached a maximum of about 50,000 feet, just within the operational ceiling of a Canberra. Clouds from the megaton detonations at Christmas Island rose higher and experiments were conducted on methods of increasing the altitude at which a Canberra could operate. A trial installation of Napier Scorpion rocket motors in the bomb bay gave a significant speed and altitude increase but had the disadvantage that, after firing, the aircraft was in effect

committed to a ballistic trajectory and no escape manoeuvre would have been possible if excessive dose rates were encountered. At the second UK trial of the system the rocket motors exploded and destroyed the aircraft, giving the aircrew an altitude record for parachute descent. The plan was then abandoned. A study was also carried out on the feasibility of using Bloodhound or Thunderbird surface to air missiles with sampling heads. There were considered to be intractable problems in designing a system which would survive sea surface impact and be readily recoverable; the atmospheric nuclear trials ended before any experiments could be carried out.

4.18 Following Operation GRAPPLE, 76 Squadron moved back to Maralinga for Operation ANTLER in the autumn of 1957. Again they were supplemented by Varsities carrying out low-level close-in fallout survey. Following this, they moved back to Christmas Island for Operations GRAPPLE X, Y and Z.

4.19 Contamination of air sampling aircraft is discussed in detail in **Appendices E** and **F**. Inhalation hazard to air sampling Canberra aircrew is discussed in **Appendix G**.

5. SAFETY REGULATIONS AT UK ATMOSPHERIC NUCLEAR TRIALS

5.1 Safety regulations are discussed in Appendix H.

6. THE RAF ACTIVE HANDLING FLIGHT

6.1 The techniques for sampling radioactive clouds developed during Operation TOTEM were extended for the later trial series. During this period No 76 Squadron RAF became the designated air sampling unit and the centre of expertise on the subject. This Squadron was a complete entity comprising aircrew, ground crew and attached medical officers who had been trained at AWRE Aldermaston. The Squadron was finally disbanded in 1960 following the cessation of atmospheric nuclear trials by the UK. Composition of the Active Handling Flight is discussed in **Appendix J**.

APPENDIX A

Summary of UK Atmospheric Nuclear Trials

Trial Name	Site	Date	Emplacement	Altitude (m)	Yield
HURRICANE	Monte Bello , WA	3 Oct 1952	In HMS Plym, off Trimouille Island	- 3	25 kt
TOTEM	Emu Field, SA	14 Oct 1953	Tower	31	10 kt
		26 Oct 1953	Tower	31	8 kt
MOSAIC	Monte Bello, WA	16 May 1956	Tower, on Trimouille Island	31	15 kt
		19 June 1956	Tower, on Alpha Island	31	60 kt
BUFFALO	Maralinga, SA	27 Sept 1956	Tower, One Tree	31	15 kt
		4 Oct 1956	Ground surface, Marcoo	0	1.5 kt
		11 Oct 1956	Air drop over Kite	150	3 kt
		21 Oct 1956	Tower, Breakaway	31	10 kt
GRAPPLE	Malden Island	15 May 1957	Air drop over sea off S tip of island	2200	300 kt
		31 May 1957	Air drop over sea off S tip of island	2400	0.7 Mt
		19 June 1957	Air drop over sea off S tip of island	2400	200 kt
ANTLER	Maralinga, SA	14 Sept 1957	Tower , Tadje	31	1 kt
		25 Sept 1957	Tower, Biak	31	6 kt
		9 Oct 1957	Suspended from balloons, Taranaki	300	25 kt
GRAPPLE X	Christmas Island	8 Nov 1957	Air drop over sea off SE tip of island	2200	1.8 Mt
GRAPPLE Y	Christmas Island	28 April 1958	Air drop over sea off SE tip of island	2500	3 Mt
GRAPPLE Z	Christmas Island	22 Aug 1958	Suspended from balloons, SE tip of island	450	24 kt
		2 Sept 1958	Air drop over sea off SE tip of island	2800	1 Mt
		11 Sept 1958	Air drop over sea off SE tip of island	2600	0.8 Mt
		23 Sept 1958	Suspended from balloons, SE tip of island	450	25 kt

Sources; References 1, 2, 5, 10, 15, 16, 29, 31, 36, 37, 39, 42 and 43 and AWE Reports held by ADS(HE) (3223)

Notes;

Maralinga Range covered a large area of desert; the locations given for detonations are code names for trigonometric survey points.

The yield of a nuclear detonation cannot be measured. It can only be estimated by indirect means such as measuring radiation output of the fireball, measuring rate of fireball growth, measuring blast effects and radiochemical analysis of residues. All these methods tend to give different yield estimates. However, it is known that some are more reliable estimates of yield, so a weighting process is used to arrive at a "best estimate of yield" . Retrospective analyses tend to revise these estimates, so a variety of figures for yields of UK trials appear in classified reports. The yields given above are those agreed between MoD Sc(Nuc)2 and specialists at AWE Aldermaston for publication in 1993 as being the most reliable available at that time.

APPENDIX B

RAF Units Taking Part in Atmospheric Nuclear Trials

Operation HURRICANE — Monte Bello — 1952

88 Squadron	Sunderland V	Transport
RAAF	Dakota	Coastal radiological survey
	Lincoln	Long-range radiological survey

Operation TOTEM — Emu Field — 1953

	Canberra B2	Air sampling

Operation MOSAIC — Monte Bello — 1956

76 Squadron	Canberra B6	Air sampling
269 Squadron	Shackleton MR1	Reconnaissance, meteorological patrol and air-sea rescue

Operation BUFFALO — Maralinga — 1956

24 Squadron	Hastings C1	Transport
49 Squadron	Valiant B1	Live drop
76 Squadron	Canberra B6	Air sampling
53 Squadron	Hastings C1	Transport
RAF Maralinga	Varsity T1 and Whirlwind HAR2	Short-range transport and radiological survey

Operation GRAPPLE — Malden Island — 1957

22 Squadron	Whirlwind HAR2	Air-sea rescue and short-range transport
24 Squadron	Hastings C1	Transport
49 Squadron	Valiant B1	Live drop
76 Squadron	Canberra B6	Air sampling
99 Squadron	Hastings C1	Transport
100 Squadron	Canberra PR7	Reconnaissance
206 Squadron	Shackleton MR1	Reconnaissance, meteorological patrol and air-sea rescue
240 Squadron	Shackleton MR1	Reconnaissance, meteorological patrol and air-sea rescue
511 Squadron	Hastings C1	Transport
1325 Flight	Dakota	Short-range transport
RAF Christmas Island	Auster 9	Insecticide spraying

NB two Avenger aircraft were carried aboard HMS Warrior for reconnaissance and transport

Operation ANTLER — Maralinga — 1957

22 Squadron	Whirlwind HAR2	Short-range transport and reconnaissance
76 Squadron	Canberra B6	Air sampling
99 Squadron	Hastings C1	Transport
204 Squadron	Shackleton MR1	Long-range reconnaissance and meteorological patrol
269 Squadron	Shackleton MR1	Long-range reconnaissance and meteorological patrol
511 Squadron	Hastings C1	Transport
543 Squadron	Valiant B(PR)1	Photo-reconnaissance
1439 Flight	Varsity T1	Short-range transport and radiological survey

Operations GRAPPLE X, Y and Z — Christmas Island — 1957-8

22 Squadron (X only)	Whirlwind HAR2	Air-sea rescue and short-range transport
24 Squadron	Hastings C1	Transport
36 Squadron	Hastings C1	Transport
49 Squadron	Valiant B1	Live drop
58 Squadron	Canberra PR7	Photo-reconnaissance
76 Squadron	Canberra B6	Air sampling
99 Squadron	Hastings C1	Transport
204 Squadron (Z only)	Shackleton MR1	Reconnaissance, meteorological patrol and air-sea rescue
206 Squadron (X only)	Shackleton MR1	Reconnaissance, meteorological patrol and air-sea rescue
217 Squadron (Y and Z)	Whirlwind HAR2	Air-sea rescue and short-range transport
240 Squadron (Y only)	Shackleton MR1	Reconnaissance, meteorological patrol and air-sea rescue
269 Squadron (Z only)	Shackleton MR1	Reconnaissance, meteorological patrol and air-sea rescue
1325 Flight	Dakota	Short-range transport
RAF Christmas Island	Auster 6	Insecticide spraying

217 Squadron was formed on 1 February 1958 with the aircrew from 22 Squadron

Sources; References 5, 10, 12, 14, 16, 29, 31, 36, 39, 42, 43 and 45.

Notes;

The above list is believed to be complete as regards major units. (In most cases a detachment was present rather than the whole unit; eg the Valiants of 49 Squadron were usually present as a Flight of four aircraft, the other Flight remaining at Wittering). While an establishment of aircraft was usually promulgated for each unit, individual aircraft were often exchanged between the trial site and the UK during the Operation.

Individual aircraft of Transport Command such as Hastings and Comets visited Maralinga and Christmas Island from time to time, and Vulcans visited Christmas Island during Operation GRAPPLE Z. Civil charter aircraft and scheduled services also served Maralinga and Christmas Island. South Pacific Air Lines operated a flying-boat service to Christmas Island for part of the period of the trials.

Military aircraft of the USA, Australia and New Zealand also visited Maralinga and Christmas Island occasionally. A few RAAF Officers attached to RAF Squadrons were involved in air sampling operations.

No 160 Wing was the early designation for all air units assigned to Operation GRAPPLE. In October 1957 this formation was renamed RAF Christmas Island.

ANTLER Round 3 and GRAPPLE Z Rounds 1 and 4 were suspended from arrays of balloons. The RAF Balloon Unit at Hullavington provided personnel and equipment and assisted in developing techniques.

Major servicing facilities were available at RAF Christmas Island. Facilities at Maralinga were more limited; eg major servicing of RAF Canberras was carried out at RAAF Edinburgh Field (see Appendix E).

APPENDIX C

Dropping and Sampling Aircraft at Trials

Operation TOTEM

Round 1 14 October 1953

Sampler	Canberra B2 WH738	[redacted]	[redacted]	[redacted]

Operation MOSAIC

Round 1 16 May 1956

Primary Upper Sampler	Canberra B6 WH978	[redacted]	[redacted]	[redacted]
Upper Sampler back-up and Photography	Canberra B6 WH979	[redacted]	[redacted]	[redacted]
Primary Lower Sampler	Canberra B6 WH976	[redacted]	[redacted]	[redacted]
Lower Sampler back-up and Photography	Canberra B6 WH962	[redacted]	[redacted]	[redacted]

Round 2 19 June 1956

Primary Upper Sampler	Canberra B6 WH978	[redacted]	[redacted]	[redacted]
Upper Sampler back-up and Photography	Canberra B6 WH979	[redacted]	[redacted]	[redacted]
Primary Lower Sampler	Canberra B6 WH976	[redacted]	[redacted]	[redacted]
Lower Sampler back-up and Photography	Canberra B6 WH962	[redacted]	[redacted]	[redacted]

Operation BUFFALO

Round 1 27 September 1956

Primary Sampler	Canberra B6 WH978	[redacted]	[redacted]	[redacted]
Back-up Sampler and Photography	Canberra B6 WH976	[redacted]	[redacted]	[redacted]
Immediate Reserve and F+3 Sampler	Canberra B6 WH979	[redacted]	[redacted]	[redacted]
F+6 Tracker	Canberra B6 WH976	[redacted]	[redacted]	[redacted]
F+7 Special to Singapore	Canberra B6 WT207	[redacted]	[redacted]	[redacted]
F+10 Tracker	Canberra B6 WJ754	[redacted]	[redacted]	[redacted]

Round 2 4 October 1956

Primary Sampler	Canberra B6 WH978	[redacted]	[redacted]	[redacted]
Secondary Sampler and Photography	Canberra B6 WH976	[redacted]	[redacted]	[redacted]
Immediate Reserve Tracker	Canberra B6 WH979	[redacted]	[redacted]	[redacted]
Singapore Tracker	Canberra B6 WT207	[redacted]	[redacted]	[redacted]

Round 3 11 October 1956

Live Drop	Valiant B1 WZ366	[redacted]
Bhangmeter aircraft	Valiant B1 WZ367	[redacted]
Primary Sampler	Canberra B6 WJ754	[redacted]
Secondary Sampler	Canberra B6 WH976	[redacted]
Background Survey and Photography	Canberra B6 WH979	[redacted]
Singapore Courier	Canberra B6 WT206	[redacted]

Round 4 21 October 1956

Primary Sampler	Canberra B6 WJ754	[redacted]
Back-up Sampler	Canberra B6 WH976	[redacted]
F+3 Tracker	Canberra B6 WH978	[redacted]
F+7 Singapore Courier	Canberra B6 WT206	[redacted]

Operation GRAPPLE

Round 1 15 May 1957

Live Drop	Valiant B1 XD818	
Grandstand aircraft	Valiant B1 XD823	
Radio Link and Target Reconnaissance	Canberra B6 WT206	
Sample Controller (Air)	Canberra B6 WH978	
Primary Sampler	Canberra B6 WH980	
Secondary Sampler	Canberra B6 WH979	
Reserve Sampler	Canberra B6 WH976	
Search and Photography	Shackleton MR1 WG510	

Round 2 31 May 1957

Live Drop	Valiant B1 XD822	
Grandstand aircraft	Valiant B1 XD823	
Radio Link and Target Reconnaissance	Canberra B6 WT206	
Sample Controller (Air)	Canberra B6 WH978	
Primary Sampler	Canberra B6 WH980	
Secondary Sampler	Canberra B6 WH971	
Photography	Shackleton MR1 WB857	
Photography	Shackleton MR1 WG510	

Round 3 19 June 1957

Live Drop	Valiant B1 XD823	[redacted]
Grandstand aircraft	Valiant B1 XD824	[redacted]
Radio Link and Target Reconnaissance	Canberra B6 WT206	[redacted]
Sample Controller (Air)	Canberra B6 WH962	[redacted]
Primary Sampler	Canberra B6 WH980	[redacted]
Secondary Sampler	Canberra B6 WH979	[redacted]
Reserve Sampler	Canberra B6 WH978	[redacted]
Photography	Shackleton MR1 WB857	[redacted]

Search and Grandstand Aircraft	Shackleton MR1 WG528	[redacted]
Malden Search and Photography	Shackleton MR1 WB821	[redacted]

Operation ANTLER

Round 1 14 September 1957

Primary Sampler	Canberra B6 WH978	[redacted]	[redacted]	[redacted]
Secondary Sampler	Canberra B6 WH976	[redacted]	[redacted]	[redacted]
Reserve Sampler	Canberra B6 WH980	[redacted]	[redacted]	[redacted]
Tracker 1	Canberra B6 WJ757	[redacted]	[redacted]	[redacted]
Tracker 2	Canberra B6 WJ754	[redacted]	[redacted]	[redacted]

Round 2 25 September 1957

Primary Sampler	Canberra B6 WH978	[redacted]	[redacted]	[redacted]
Secondary Sampler	Canberra B6 WH976	[redacted]	[redacted]	[redacted]
Reserve Sampler and Tracker	Canberra B6 WJ757	[redacted]	[redacted]	[redacted]
Forward Area Radiological Survey	Varsity T1 WL639	[redacted]	[redacted]	[redacted]
Cloud Tracker	Varsity T1 WJ675	[redacted]	[redacted]	[redacted]
Short Range Radiological Survey	Varsity T1 WL635	[redacted]	[redacted]	[redacted]

Round 3 9 October 1957

Primary Sampler	Canberra B6 WH978	[redacted]	[redacted]	[redacted]
Secondary Sampler	Canberra B6 WH976	[redacted]	[redacted]	[redacted]
Tracker 1	Canberra B6 WJ757	[redacted]	[redacted]	[redacted]
Tracker 2	Canberra B6 WJ754	[redacted]	[redacted]	[redacted]
Cloud Tracker	Varsity T1 WJ941	[redacted]	[redacted]	[redacted]

Operation GRAPPLE X 8 November 1957

Live Drop	Valiant B1 XD825	
Grandstand aircraft	Valiant B1 XD827	
Air Controller	Canberra B6 WH978	
Primary Sampler	Canberra B6	
Secondary Sampler	Canberra B6	
Target Reconnaissance and Tertiary Sampler	Canberra B6	
Lookout 1	Shackleton MR1 VP289	
Lookout 2	Shackleton MR1 WB826	

Lookout 3	Shackleton MR1 WG508	

Operation GRAPPLE Y 28 April 1958

Live Drop	Valiant B1 XD824	
Grandstand aircraft	Valiant B1 XD822	
Stand-off aircraft 1	Valiant B1 XD827	
Stand-off aircraft 2	Valiant B1 XD818	
Air Controller	Canberra B6 WJ754	
Primary sampler	Canberra B6 WJ757	
Secondary Sampler	Canberra B6 WH980	

[redacted]

Tertiary Sampler	Canberra B6 WH976	[redacted]
Scorpion Controller	Canberra B6 WT206	[redacted]
Scorpion 1	Canberra B6 WT208	[redacted]
Back-up Sampler	Canberra B6 WH978	[redacted]
Cloud Reconnaissance and Photography	Shackleton MR1 WB850	[redacted]
Radiological Survey	Shackleton MR1 WB859	[redacted]
Radiological Survey	Shackleton MR1 WB826	[redacted]

[redacted]

Operation GRAPPLE Z

Round 1 22 August 1958

Air Controller	Canberra B6 WJ757	[redacted]	[redacted]	[redacted]
Primary Sampler	Canberra B6 WH979	[redacted]	[redacted]	[redacted]
Secondary Sampler	Canberra B6 WJ754	[redacted]	[redacted]	[redacted]
Tertiary sampler	Canberra B6 WH978	[redacted]	[redacted]	[redacted]
Photography	Shackleton MR1 WB851	[redacted]	[redacted]	[redacted]
Radiological Survey	Shackleton MR1 WB851	[redacted]	[redacted]	[redacted]

Round 2 2 September 1958

Live Drop	Valiant B1 XD822	[redacted]
Grandstand aircraft	Valiant B1 XD818	[redacted]
Air Controller	Canberra B6 WJ757	[redacted]
Primary Sampler	Canberra B6 WH979	[redacted]
Secondary Sampler	Canberra B6 WJ754	[redacted]
Tertiary sampler	Canberra B6 WH976	[redacted]
Reconnaissance and Photography	Shackleton MR1 WB835	[redacted]
Radiological Survey	Shackleton MR1 WB826 & VP289	[redacted]

Round 3 11 September 1958

Live Drop	Valiant B1 XD827	
Grandstand aircraft	Valiant B1 XD824	
Air Controller	Canberra B6 WJ757	
Primary Sampler	Canberra B6 WH980	
Secondary Sampler	Canberra B6 WJ754	
Tertiary Sampler	Canberra B6 WH979	
Reconnaissance and Photography	Shackleton MR1 WB828	
Radiological Survey	Shackleton MR1 VP265	

Round 4 23 September 1958

Air Controller	Canberra B6 WH979	[redacted]
Primary Sampler	Canberra B6 WJ754	[redacted]
Secondary Sampler	Canberra B6 WH976	[redacted]
Tertiary Sampler	Canberra B6 WH980	[redacted]
Reconnaissance and Photography	Shackleton MR1 VP263	[redacted]
Radiological Survey	Shackleton MR1 WB857	[redacted]

Sources; Reference 45 and files held by ADS(HE) (4401, 3223)

APPENDIX D

Fate of ex-Trials Aircraft

Canberra B6	WH962	To RAF Catterick for firefighting	31/9/71
Canberra B6	WH976	To RAF Catterick for firefighting	30/1/71
Engines 5799/646567 (to 27/7/56), 1583/657072 (from 27/7/56), 1532/657041			
Canberra B6	WH978	Struck Off Charge and scrapped, Wroughton	31/10/71
Engines 6371/648917, 6366/648912			
Canberra B6	WH979	Struck Off Charge and scrapped, Wroughton	31/10/71
Engines 6339/648885, 6336/648882			
Canberra B6	WH980	Struck Off Charge and scrapped, Wroughton	31/10/71
Engines 6382/648928, 6372/648918			
Canberra B6	WJ754	Sold to BAC Warton	31/11/67
Engines 5621/646389 (to 27/7/56), 6300/648846 (from 27/7/56), 5690/646458			
Canberra B6	WJ757	Sold to BAC Warton	31/11/67
Canberra B6	WT206	Struck Off Charge and scrapped, Wroughton	31/10/71
Canberra B6	WT208	Sold to BAC Warton	30/11/67

Source; Record cards held by RAF Museum, Hendon (M59948)

All Valiants were grounded in 1965 and subsequently scrapped at Gaydon, Marham and Wyton, with the sole exception of XD818 which is on display at the RAF Museum, Hendon.

All ex-trials Shackletons and Varsities have been scrapped.

APPENDIX E

Decontamination Operations at Maralinga, RAAF Edinburgh Field, Christmas Island and RAF Upwood

E1 Following Operations MOSAIC and BUFFALO, the handling and decontamination of all active aircraft was carried out by the Active Handling Flight at a prepared site on the airfield at Maralinga (see **Reference 22**). Personnel were supplied by the RAF. (See **Appendix J**).

E2 [redacted] of the RAF Medical Branch was in charge of the Health Physics aspects of all personnel employed on the site and in this capacity he controlled the work of the decontamination and handling crews.

E3 Advice on decontamination was supplied by [redacted] an AWRE staff member of his Group, who supervised the actual decontamination work.

E4 The workforce was two Sergeants, five Corporals and 11 Airmen, some of whom had had training and experience during Operation MOSAIC under [redacted].

E5 The duties of the Active Handling Flight were to;

- Marshall active aircraft
- Assist the aircrew to disembark
- Refuel the aircraft
- Remove sample filters
- Decontaminate the aircraft
- Carry out monitoring as necessary

E6 Servicing and maintenance operations on active aircraft were carried out by 76 Squadron personnel at the decontamination area.

E7 The Active Handling Flight was based at the Southern end of the runway. The decontamination area (which was unfinished at the time of BUFFALO) consisted of a large rectangular pan built with a slight slope towards one corner in order to provide efficient drainage. There was an access taxi track from the runway to the washdown area, and an approach road from the airfield to the decontamination centre. Effluent from the washdown pan was collected in two concrete gutters and piped into a large soakaway pit. The surface of the pan was covered in corticene (a material used for warship deck covering and very similar to linoleum). The decontamination building housed an office, changing rooms and showers. There were no facilities for stripping down engines or other equipment. Only one aircraft could be worked on at a time. Plans are given in **References 22, 25 and 31**.

E8 Changing facilities were provided in a Health Physics building.

E9 The protective clothing employed when working in contaminated areas comprised;

- The AWRE white protective suit with hood
- White rubber half Wellington boots or overshoes
- White cotton or PVC gauntlets
- White beret or skull cap (optional)

For wet decontamination work, PVC leggings, coverall, hood and sea boots were worn. Respirators were worn when there was an inhalation hazard, e.g. when handling a sample filter or when hosing down an aircraft.

E10 Laundry of all protective clothing used at Operation BUFFALO (**Reference 22**) was carried out in a dedicated active laundry equipped with boiler, detergent mixing tank, washing machines, steeping tanks and drier. Forced input and exhaust ventilation was fitted to the building. The washing machines and drier were connected to the exhaust system. Dirty sorting was done in fume cupboards which were connected to the extract system. All clothing was monitored before and after washing. The maximum permissible contamination level after washing was 60 counts/sec beta and gamma.

E11 Prior to use in the Operation, all aircraft were sprayed externally with the specially developed AWRE barrier paint. This was basically an aqueous solution of polyvinyl acetate with an inert pigment. It provided an easily removable barrier between the contamination and the existing paint finish, being water soluble when fresh, easily applied without special equipment, and water resistant once dry. It was easily removable by the special stripper, an aqueous solution of sodium carbonate with a wetting agent and thickened with sodium alginate, which rendered it once again water soluble. Washing down with fresh water provided a high degree of decontamination. Application by eight airmen took 1 - 2 hours and removal about four days.

E12 The Canberras were modified to minimise the risk of internal contamination. Provision was made for air intakes to cabin filtration and main spar cooling ducts to be blanked off during flight in radioactive clouds. All cooling air such as that for the inverter and generator was ducted out of the aircraft. Filtration was fitted to the ventilated flying suit system.

E13 The Varsities were sprayed with barrier paint but no special modifications were carried out, as they were not intended to fly through the radioactive clouds.

E14 All active aircraft taxied to the Active Handling Flight immediately on landing after a cloud sampling or tracking sortie. They were marshalled to the aircraft monitoring position. Waiting ground crews stood well upwind.

E15 As soon as engines were stopped two members of the ground grew opened up the main entrance hatch using a piece of polythene sheeting on the handle to avoid contaminating their gloves. A previously prepared brown paper cut-out was then taped round the entrance hatchway to guard against contamination of the aircrew's clothing. Before they disembarked they were given overshoes.

E16 For any operation which involved touching the aircraft, ground crew were instructed to make use of polythene sheet to avoid contaminating themselves. Ground support equipment at risk of contamination , e.g. refuelling hoses, was wrapped in polythene.

E17 As soon as possible after arrival, aircraft were monitored at predetermined positions on the airframe. This process was repeated at intervals to obtain a picture of decay rates. The policy was to allow as long a period as possible before re-using a contaminated aircraft again.

E18 Contamination can be regarded as 'fixed or 'loose'. Fixed contamination is held to a surface largely by chemical action between the contaminant and the surface on which it is deposited, or by absorption into porous surfaces. Removal of fixed contamination can be achieved by removing the surface by abrasion, or by using complexing agents to render the contamination soluble.

E19 Loose contamination rests on a surface held either by oil or grease films, electrostatic attraction, or by entrapment in crevices. It can be removed by brushing, vacuum cleaning or washing.

E20 The primary aim of decontamination at the nuclear trials was to enable the aircraft to be made fit for further operations without presenting undue hazard to the aircrew or others working on or in it. The secondary aim was the reduction to safe levels of dose rates to those working on or in the aircraft so that routine servicing and maintenance could proceed without the necessity of personnel having to wear protective clothing and follow a washing and monitoring routine.

E21 Early experience indicated that contamination on cloud sampling aircraft tended to be impacted into the skin or lodged in crevices and hence difficult to remove. Flying contaminated aircraft through heavy rain was ineffective; washing on the ground, while effective, required copious supplies of water (at a premium in Australia) and created large quantities of potentially contaminated effluent. Gelled degreasant (Swarfega) and latex emulsion were generally effective but the best approach was to protect the surface from contamination by a strippable coating.

E22 The AWRE barrier paint was intended to prevent contamination adhering to the aircraft structure. In theory decontamination should have been achieved by washing off the paint.

E23 At Operation BUFFALO, the external dose rate to those working in proximity to contaminated aircraft shortly after cloud penetration from fixed contamination was acceptable in the sense that most planned tasks were achievable without any person exceeding the dose limits set in advance for the operation (5 mSv per week X + gamma). The hazard from loose contamination was however more significant and most decontamination effort was thus directed towards reducing this. As a precaution a policy decision was taken to carry out only the minimum essential servicing on an aircraft after landing from a cloud sampling sortie, leaving it for as long as practicable for radioactive decay to reduce the hazard before carrying out routine servicing and maintenance. After the final detonation of the operation, more time was available for decontamination and more effort was directed towards removal of the fixed contamination.

E24 Dose limits were set out in the Radiation Safety Regulations Maralinga. Very few of the AHF had total doses approaching the limits.

E25 First attempts centred on removal of barrier paint, but on the cloud sampling aircraft this had been applied for Operation MOSAIC four months before. Little decontamination had been attempted during Operation MOSAIC, though further coats of barrier paint had been applied. These had age-hardened to such a degree that it was almost impossible to remove. For the first two rounds of Operation BUFFALO, therefore, decontamination was restricted to a quick scrub with detergent and a wash with steam or water jets. Following Round 3, a technique was evolved for removal of the barrier paint. Stripper was applied, allowed to work for two hours and then cleaned off with steam jets. After Round 4 more time was available. Aircraft were given a good external clean with detergent, barrier paint remover, or, on greasy surfaces, emulsifying solvent cleaner. Fixed activity was reduced by use of abrasives or complexing agents. It was believed that the original skin condition of the

Canberras was poor, and that if greater attention had been given to obtaining a smooth gloss finish before applying barrier paint, subsequent decontamination would have been considerably easier.

E26 After each cleaning, aircraft were monitored with a Type 1320 instrument, testing for smearable activity by the standard AWRE method using filter paper.

E27 On Operation BUFFALO, 4 Canberras and one Varsity were passed through the active area after Round 1, 3 Canberras and 2 Varsities after Round 2, 2 Canberras and 2 Varsities after Round 3 and 2 Canberras and 1 Varsity after Round 4. The degree of contamination these aircraft varied considerably from aircraft to aircraft and on different parts of the same aircraft. Canberra WJ 976 which had been used for air sampling on MOSAIC and BUFFALO gave the following mean dose rates after Round 3;

at H + 2.5 hours	Airframe	13 mSv/hour
	Wings	21 mSv/hour
	Tailplane	24 mSv/hour
	Engines	Over 30 mSv/hour at one metre
at H + 67 hours	Airframe	0.14 - 0.17 mSv/hour
	Wings	3 - 4 mSv/hour
	Tailplane	4 - 5 mSv/hour
	Engines	14 mSv/hour

E28 The Canberras used at BUFFALO became highly contaminated on the skin, in the rudder fairings, around the elevators and in the engines. About two day's work with stripper and a steam cleaner lowered contamination on external surfaces to a level that was regarded as safe. Parts of the elevators, the rudder fairings and inside the engine cowlings could be partially decontaminated but not completely so.

E29 The extent of contamination on the interiors of the Canberras was not very great, as the air conditioning system incorporated filters. Non-pressurised spaces such as wheel wells and the interior of the rear fuselage were not heavily contaminated and wiping with a detergent-soaked cloth followed by a wipe dry was usually adequate. Interiors of flaps were generally greasy and dirty and tended to trap contamination, though they could usually be cleaned to an acceptable level by the use of stripper or emulsifying solvent cleaner. Cowlings were not difficult to clean internally. A bad contamination trap existed in the gap between the all-moving tail and the fuselage fairing. It could not be cleaned without dismantling. Radiators were effectively cleaned with emulsifying solvent cleaner and steam jet. Though the oily surfaces tended to trap contamination, they also acted as a barrier film. A full day's work by 8 - 10 airmen, all that could be employed efficiently on one aircraft, lowered contamination on external surfaces to a safe figure for active handling by a trained ground crew.

E30 During BUFFALO, all the aircraft required their routine servicing, which was carried out by the Squadron ground crew. This entailed;

Canberras

Daily Service	7 men, 30 minutes each
Primary Service (7 days)	9 men, one hour each
Primary Star (28 days)	9 men, 2 hours each

Varsities

Intermediate	9 men, two hours each

As the decontamination area could only accommodate one aircraft at a time, it was necessary to establish a temporary active servicing area on the airfield tarmac.

E31 On the Varsities, internal contamination was worse but not excessive in the sense that it could give rise to significant dose-rates to personnel. Wiping with damp and dry rag usually sufficed, though due to their greater size and complexity it was more laborious than in the case of the Canberras. Flaps were not easy to decontaminate due to their complex structure. Similarly, the cowlings, which were double skinned, also tended to be contamination traps. Although the Varsities were never severely contaminated, active handling procedures had to be used when opening the cowlings during normal servicing, and at the end of Operation BUFFALO some engines were still sufficiently contaminated to warrant changing before flying the aircraft back to the UK.

E32 Engine decontamination posed problems due to contamination entrapped on greasy surfaces or impacted onto the inner surfaces of ducts. No facilities existed at Maralinga (or Christmas Island) for deep maintenance of engines. Some amelioration was possible to the Hercules engines of the Varsities by the use of emulsifying solvent cleaner and steam jets but thorough cleaning would have involved removing the cooling air baffles which the RAF were not prepared to do at Maralinga. The Avons of the Canberras could be wiped down externally; considerable internal decontamination could be achieved by spraying a water/kerosene/Turbex mixture into them while running (albeit at the cost of spreading the contamination over the parking area). Some experimental work was done at Maralinga to develop engine decontamination techniques; these were later put into practice when it was decided to concentrate all RAF engine decontamination activities at St Athan (see **Appendix F**).

E33 It was realised that final clearance of the aircraft used at Operation BUFFALO to a level where work on them could be entirely unrestricted would not be possible at Maralinga. Certain work would still require the personnel to wear protective clothing. A note to this effect was made on the cover of each aircraft's Form 700 and a radiological history of the aircraft was inserted. Subsequently, further decontamination activities were concentrated at RAAF Edinburgh Field and RAF Upwood(see **References 27** and **41**).

E34 It was noted that, while the Active Handling Flight had experience at Operation MOSAIC, the Squadron line crews did not. While these last were wary at first of radiological hazards, familiarity tended to breed contempt and, towards the end of Operation BUFFALO, carelessness. This resulted in the spread of contamination to tool boxes and crew rooms. Only one trained Health Physics officer was available for Operation BUFFALO. This was judged inadequate and was improved for later operations.

E35 The active laundry at Maralinga worked well. On shot days at BUFFALO, about 50 sets of clothing were issued daily, with 20 replacements during the afternoon. Large quantities of polythene sheet, tape etc were also required.

E36 **Reference 35** gives appendices showing beta and gamma monitor readings on typical aircraft before and after decontamination.

E37 At Operation GRAPPLE, a decontamination area was set up at RAF Christmas Island. For details see **Reference 28** Part 2. The main task was handling of 76 Squadron Canberras. Some Shackletons did acquire adventitious contamination, though not on the scale of that experienced by the Varsities in Australia.

E38 The original establishment for the Active Handling Flight for this Operation was as shown in Appendix J. After the first detonation, it was found that this team was not employed economically. It was thereafter reconstituted as;

a) Monitoring Party

b) Decontamination Party

c) Servicing and Handling party

Parties (a) and (b) were considered part of the permanent establishment of the AHF.

E39 The purpose of decontamination was to reduce conditions hazardous to aircrew and ground crew to one that presented a limited and controlled problem. After decontamination, an aircraft had its initial servicing in the Active Area under Health Physics supervision. Subsequently, it was released for normal servicing in the clean area, up to the last degree of servicing carried out in the Active Area. The Form 700 was annotated to indicate the degree of contamination.

E40 Operation ANTLER followed closely after GRAPPLE and most of the Canberras flew straight to Maralinga from Christmas Island (see **Reference 35**). During ANTLER all decontamination and nearly all first line servicing was carried out at Maralinga and second line servicing at Edinburgh Field. At Maralinga the responsibilities were divided. RAF Regiment personnel were employed under the supervision of the Health Physics Adviser in monitoring aircraft. The technical RAF personnel were responsible for decontamination and servicing of the aircraft and for assisting AWRE personnel in removing sample filters. At Edinburgh Field the RAF Regiment NCO was responsible for monitoring and protective measures, under the supervision of the RAF Senior Engineering Officer, who acted under advice from the Health Physics Adviser at Maralinga.

E41 As soon as a contaminated aircraft landed at Maralinga it was taxied to the decontamination area where it came under Health Physics control. The crew left the aircraft under supervision, being monitored as they emerged from the hatch, which was masked to prevent contamination rubbing off on to them The aircraft was then monitored and if judged significantly contaminated was refuelled and left for the radioactivity to decay. Decontamination was not then attempted until several days had elapsed.

E42 Aircraft decontaminated at Operation ANTLER were as follows.

After Round 1	After Round 2
Canberra WH 976 (Primary Sampler)	Canberra WH 978 (Primary Sampler)
Canberra WH 976 (secondary Sampler)	Canberra WH 976 (Secondary sampler)
Canberra WJ 757 (Tracker)	Canberra WJ 757 [1] (Tracker)
Canberra WJ 754 (Tracker)	Varsity WJ 941 (Tracker)
	Varsity WL 639 [2] (Rad Survey)

Notes: 1 This aircraft was turned round and sent on a second sortie
2 This aircraft was unintentionally contaminated

E43 Although never used, the decontamination facilities at Edinburgh Field were judged to be adequate. When an aircraft was brought into the hangar for second line servicing it was surrounded by a barrier, after which access to it was only permitted via Health Physics control. It was then monitored by Health Physics personnel, who specified protective measures to be taken.

E44 Some Canberras with deteriorated paint finish required several scrubbings with detergent solution to reduce external contamination to an acceptable level. It was considered that the old surface finish was porous and abrasion was revealing layers of contamination from previous trials.

E45 Engines were first sprayed with emulsifying solvent compound (ESC) prepared by AWRE. This was then cleaned off with a steam jet. Only the areas up to the swirl vanes were so treated. A similar treatment was given to undercarriages and their bays, the insides of the engine cowlings and other greasy or oily parts. By this time, contamination was restricted to small areas and the aircraft could be removed from the decontamination area.

E46 Further treatment consisted of polishing with Southend paste. Persistent areas of contamination included the oil pump and filler cap, main fuel pipe and throttle rods, lower edge of the forward bulkhead, starter cartridge housing and the dome over the cartridge holder. On the airframe problem areas were the air brakes, upper and lower flap surfaces, inside the aileron shrouds and the lower outboard shelf in the undercarriage bay. All vents and hatches were difficult to clean. The inside of the fuselage was cleaned with an industrial vacuum cleaner and by wiping with rags. This proved a long and arduous task. The ventilation system was particularly difficult to decontaminate.

E47 Conclusions included;

a) Radioactive decay gave a significant reduction in dose rate over the first few days. It was advantageous therefore to delay decontamination as long as possible.

b) It was considered virtually impossible to completely decontaminate any aircraft which had been subject to any reasonable degree of activity. Although the Canberras dealt with were cleaned to Primary Star standard, this did not and could not include all rectifications arising

from this inspection. Neither could this standard provide protection against carelessness or ignorance exercised during handling of the aircraft.

c) Following from this, it was recommended that no active aircraft should ever be serviced or operated outside Health Physics control. Suitable protective clothing and monitors should always be available. When on the ground the aircraft should always be in a controlled area.

d) Squadron or other personnel handling active aircraft should regularly be given organised instructions on the hazards involved and methods of protection.

e) Although piston engined aircraft at ANTLER were less exposed, the opinion formed was that piston engines were easier to decontaminate than jet engines.

E48 In May 1958 a visit to the RAF Special Servicing Flight, RAAF Edinburgh Field, near Adelaide, was made by [redacted] and [redacted] **(Reference 41)**.

E49 The RAF Holding Unit, Edinburgh Field, was responsible for equipping all RAF units in Australia. For the servicing of radioactively contaminated aircraft it was provided with a Special Handling Flight based in Hangar 594.

E50 The purpose of the visit, which was carried out following Operation GRAPPLE Y at Christmas Island, was to review the progress of the works services recommended for the safe handling of contaminated aircraft of No 76 Squadron, based for the period of the trials at Edinburgh Field.

E51 The safety standards in force at the time of this visit were laid down by AWRE Aldermaston and the Australian Atomic Weapons Tests Safety Committee, who were also the final arbiter in matters affecting Australian life and property.

E52 Aircraft were decontaminated by work parties provided by the RAF and supervised by a scientist from AWRE.

E53 For the servicing of contaminated aircraft, a Special Handling Flight was established under [redacted], RAF Regt., comprising one Flight Sergeant, one Corporal (airframe), one engine mechanic and one airframe mechanic.

E54 The Active Aircraft Servicing Pen consisted of about one third of Hangar 594 and could accommodate one Canberra at a time. The pen was enclosed by movable steel fencing on two sides and by permanent walls on the other two so that when the aircraft was positioned and the fencing set up entry and exit by personnel could only be through one door to the Health Physics Control Room.

E55 A Special Equipment Servicing Bay was provided for decontamination of small components using degreasing baths.

E56 The Health Physics Control Room separated the Active Aircraft Servicing Pen and the Special Equipment Servicing Bay from the rest of the hangar. It was equipped with a shower, washbasins and a Type 1027 hand-and-foot monitor. It was separated by a shoe barrier into clean and dirty areas and was supervised by an airman Health Physics Monitor. He was responsible for:

- Issuing protective clothing and film badge
- Monitoring all leaving the area
- Disposal of contaminated clothing into active waste bins
- Supervising decontamination of personnel and items
- Collecting film badges

A portable air sampler was available for estimating radioactivity in air in the hangar.

E57 Complete sets of servicing tools for every trade engaged in Minor Servicing were permanently held in the Active Area to minimise the risk of contamination spread.

E58 Collecting tanks for effluent were located behind the hangar in an enclosed area, which also included parking for vehicles used for conveying liquid effluent or items for decontamination to the Aircraft Decontamination Area on the airfield. Waste was transferred by air to Maralinga fortnightly

for final disposal. Contaminated aircraft engines were wrapped in absorbent material, cocooned in PVC bags, crated and sent to RAF St Athan by sea for decontamination (See **Appendix F**). Cabin air filters from cloud-sampling Canberras were capped, cleaned externally, crated and sent to AWRE for disposal.

E59 The Airfield Decontamination Area comprised a pan with effluent sump (3,500 gallon capacity, fitted with overflow alarms) and evaporator, and a small Health Physics Control building with shower and washbasins (see also **Reference 25**).

E60 All personnel regularly employed in servicing active aircraft wore PM1 type film badges. These were changed monthly and processed at Maralinga.

E61 The report also includes tables of results of smear surveys in Hangar 594 (inside and outside the active area) and the Airfield Decontamination Area.

E62 In August 1960 a visit was made to RAF Upwood, Huntingdonshire, to examine surviving 76 Squadron Canberras that had been used in the air sampling role at the UK atmospheric nuclear trials. The examination was carried out by [redacted] and [redacted] of RAF/AWRE and [redacted] of AWRE Health Physics (**Reference 27**).

E63 No 76 Squadron was scheduled to be disbanded following the cessation of atmospheric trials by the UK and the consequent lapse of the requirement for a air sampling unit. Of the 8 aircraft held by 76 Squadron, 6 had been flown through radioactive clouds. (one, WJ 754, had been through 11 clouds including the whole of the GRAPPLE series.) The state of the aircraft was required to be assessed so that disposal arrangements could be made.

E64 Since the end of 1959, these aircraft had been kept at Upwood under Health Physics control. They were used for the intelligence gathering operation MEDSTEAD in 1960 (see para **4.9** above). Since return to the UK from Australia no significant contamination of persons, components or airframes had been recorded. "Significant" in this context meant no greater than one-tenth of the then occupational level of 37 kBq/m^2. Compare, for instance, the sheltering limit of 1.8×10^5 kBq/m^2 for external dose from ^{137}Cs in use today.

E65 It was the practice to tie in radioactive clearance with servicing. Thus "Cleared to Primary Star" meant that all maintenance associated with Primary Star could be carried out without Health Physics intervention, as no resuspendable particulates would be encountered in the areas to which access would be required.

E66 Canberra WJ 754 was chosen for detailed survey as it had had the most exposure. In previous surveys it had been possible to smear areas corresponding to the standard 100 cm^2 smear. In this survey more attention was paid to small components such as rivets, nuts, split pins and electrical cables where such areas were not accessible.

E67 The following points were noted.

a) The tail cone was a known contamination trap. It was found that in many cases the remaining detectable activity was often on a very small area such as a speck of barrier paint on a nut face or a small agglomeration on a split pin. General levels were rarely above background in the various compartments of the tail cone area. The highest count recorded was 500 dpm on a shielded 1320 probe (equivalent to about 90 kBq/m^2 but over a much smaller area).

b) It was possible to remove old hardened barrier paint by scraping, though considerable force was required. Paint from the earlier operations was still present under more recent layers. All paint showed activity in the range 10 - 100 kBq/m^2.

c) Activity was associated with surfaces which had caught drips of barrier paint when it was stripped off. Presence of activity in some compartments suggested that it had been washed in during decontamination and not acquired during air sampling.

d) Contamination around rivet heads was insignificant.

e) Contamination around hatches was trapped in felt sealing strips and could be effectively removed by replacing these. Contamination (fixed only) was also detected in felt seals in the cabin cooling system.

E68 It was concluded that the remaining contamination on this aircraft was very low both by contemporary standards and by the standards of today and presented no hazard to those working on it.

E69 The fate of ex-trials contaminated aircraft is given in **Appendix D**.

Sources; References 22, 25, 27, 31, 35 and **41** and files held by ADS (HE) (M59948)

APPENDIX F

Decontamination Operations at RAF St Athan

F1 Very early experience at the US Operation CROSSROADS (see **Reference 15**) indicated that military equipment contaminated by fallout could be extremely difficult to decontaminate. This was confirmed at Operation HURRICANE, when Royal Australian Air Force Lincolns used for cloud tracking acquired significant surface contamination, particularly of the oily surfaces of engines. There was also some persistent contamination by particulates impacted into the inner surfaces of supercharger ducts. The problems became significantly worse in following operations, in which Canberra aircraft carrying samplers were flown through the radioactive clouds. While airframes could be washed down and decontaminated to levels permitting virtually unrestricted access at the trials location, decontamination of engines was a specialised task allotted to No 32 Maintenance Unit at RAF St Athan.

F2 Decontamination procedures involve stripping the engines down and immersing sub-assemblies in baths of degreasing solvent. Mild abrasion was used as necessary.

F3 There is evidence from the Forms 540 of No 32 MU that work on decontaminating engines began as early as July 1957. Two Avon Mk 10901 (ex-Canberra B6) were received during this month; work was completed the next month. During September 1957 4 Hercules Mk 263 engines (ex-Varsities) were received; this task was completed by the end of October. Between October 1957 and December 1958 further Avon engines must have been fed into the Unit, although there is no specific mention in the Forms 540 and no further decontamination was carried out during this period.

F4 During December 1958 a visit was made to the Unit by the then [redacted] and [redacted], RAF Radiobiologists at AWRE Aldermaston. This visit showed up shortcomings in the procedure for handling contaminated engines, particularly in the route of waste disposal. It was reported that the effluent from the degreasing baths was put into 40 gallon drums and dumped in the Bristol Channel from RAF marine craft from the Marine Craft Unit at Porthcawl. Solid waste was incinerated on the station. Both these practices were stopped immediately. On 22 December 1958 a meeting was held at St Athan, chaired by DD Air Eng 1 RAF, to discuss and finalise engine bay work services and special equipment requirements to enable the Unit to proceed with the work of decontaminating contaminated Avon engines from aircraft that had flown at Operation GRAPPLE. At that time 13 engines were awaiting decontamination. The meeting agreed to a number of work services that were essential to satisfy minimum medical requirements. The meeting also approved the protective clothing necessary.

F5 On 7 April 1959 a further meeting was held at St Athan to discuss the disposal of radioactive waste. [redacted] of the then Ministry of Housing and Local Government was actioned to write to the Air Ministry recommending that although aqueous based waste could be disposed of through the local drainage system, paraffin based waste should be disposed either via AWRE Aldermaston or by sea dumping. Similarly, Solid waste could be either sent to Aldermaston or buried 6 feet deep at the local Cowbridge rubbish tip. It appears that properly controlled sea dumping of sealed drums was instituted thereafter.

F6 Decontamination of aircraft engines recommenced on 20 April 1959, [redacted] being attached to the Unit from 16 April as a medical observer. By this time, a special bay had been set up with segregated dirty, clean and changing areas. Adequate protective clothing was issued. Film badges were issued and annual medical examinations with blood tests were carried out.

F7 On 11 April 1960 a meeting was held at St Athan to discuss the standards of decontamination of the engines. The medical representatives from Aldermaston and HQ Maintenance Command advised that no relaxation of the decontamination standards could be accepted. They expressed satisfaction with the manner and speed with which the work was progressing.

F8 The date for the completion of decontamination tasks cannot be exactly determined but it is likely that it was finished by June 1962. In all 26 Avon Mk 109 and 4 Hercules Mk 263s were thought to have been decontaminated.

F9 The building in which the engine decontamination was carried out has since been demolished.

Source; Files held by ADS(HE) (M59948)

APPENDIX G

Cabin Air Filtration in Canberra Aircraft

G1 Early experience at Operation TOTEM (**Reference 18**) indicated that measurable radioactive contamination could be found inside a Canberra after cloud penetration. Smear samples indicated typically a few dpm/cm^2 at 3 days after burst. There was evidence that this was not a mixture of fission products, but predominantly radioisotopes of iodine; rubber items inside the cockpit appeared to pick up activity preferentially. In one experiment, a latex patch attached to a flying suit in the proximity of the air inlet demonstrated preferential uptake of iodine, probably in elemental form. A projected experiment to install in the cockpit air intake an open-weave carbon cloth filter of the type used in respirators ran out of opportunity.

G2 A manuscript note was written on this subject by [redacted] of AWRE in 1956 (**Reference 26**). It is also discussed in **References 17 and 21**.

G3 The Canberra was fitted with a cabin accommodating a maximum of four aircrew and comprising a small compartment at the forward end of the fuselage capable of being pressurised. A system bled air from the engine compressors to provide pressurised, filtered, conditioned air to the cabin. An oxygen system was also provided.

G4 After Operation TOTEM a supplementary filter designed at AWRE was incorporated into the system. The 1955 version consisted of a prefilter, a heat exchanger and an 'absolute' filter in series, mounted in the wing. Each filter unit was approximately 380mm x 200mm x 200mm and fabricated from 3mm sheet steel. Units were not readily interchangeable between aircraft.

G5 For a particle size of 0.5 micron, the filter efficiency was assessed at 99.995%. In a typical radioactive cloud of 1-hour fission products this would result in an activity concentration of 370 kBq/m^3 in the filtered air.

G6 The effect of pressurisation was to increase the pressure in the cabin to that at half the aircraft's altitude. At a typical cloud penetration altitude of 50,000 feet this would increase the concentration of 0.5 micron particulates in the filtered air by a factor of three, to 1.11 MBq/m^3.

G7 Dale, in **Reference 17**, showed that the concentration of 1-hour fission products in breathing air necessary to give a dose of 30 mSv in 24 hours is 4.44 MBq/m^3.

G8 By proportionality, a typical cloud penetration of 5 minutes would result in a potential dose from breathing cabin air of 26 microSieverts. This was trivial compared to the external dose from the cloud. It was further reduced by the requirement laid down in the safety procedures to breathe 100% oxygen from time of proximity to cloud until landing. Breathing oxygen reduced the amount of cabin air breathed by a factor of five. There are further complications in allowing for the proportion of fission products that are gaseous and so not trapped by the filters, but the conclusion is always the same; i.e. that the internal dose to an air sampling crew was a negligible fraction of the external dose.

G9 Following Operation ANTLER in 1957, thyroid counts were taken on a number of participants including some 76 Squadron aircrew. In no case was any activity detected in the thyroid. This gives some confidence that internal dose to Canberra aircrew from radioisotopes of iodine was negligible.

Source; References 17, 18, 21, and **26** and files held by ADS(HE)

APPENDIX H

Safety Regulations at UK Atmospheric Nuclear Trials

H1 Standards of radiological protection for servicemen and civilians at the UK atmospheric nuclear trials were based on those in force at the time at AWRE Aldermaston. These standards were in a state of flux in the 1950's.

H2 At the time of Operation HURRICANE in 1952, no statutory regulations had been promulgated. Consequently, some form of limitation had to be devised by the Ministry of Supply and the Admiralty. The ICRP had recommended in 1950 a maximum dose for workers in the nuclear industry of 0.5 roentgens per week to whole body and 1.5 roentgens per week to skin. Exposures in the nuclear industry would be expected to be fairly uniform over time, while exposure at a nuclear trial would be expected to be high at first, declining rapidly with time. It was expected that the vast majority of trial participants would not be exposed to dose rates higher than the ICRP weekly limit. However, it could be anticipated that some essential tasks might entail exposure to higher rates. Thus the concept was proposed of 'integrated dose' which it would be permissible to receive provided that the exposure was followed by a sufficient period of non-exposure. A nuclear trial was expected to cover a period of about ten weeks. The ICRP limit for this period would be 5 roentgens to whole body and 15 roentgens to skin.

H3 The following limits were thus set for Operation HURRICANE:

a) The Normal Working Rate of not more than 0.3 Roentgens Effective Physical (rep) per day of which the gamma component was not to exceed 0.1 roentgens.

b) A Lower Integrated Dose of up to 15 rep in a ten-week period in one or more exposures, of which the gamma component was not to exceed 3 roentgens. Persons receiving this dose were not to be exposed further for a period of at least six weeks.

c) A Higher Integrated Dose of up to 50 rep in one or more exposures of which the gamma component was not to exceed 10 roentgens. This was expressly for key personnel who might be required to respond to an accident or emergency. Persons so exposed were not to be exposed further for a period of at least one year. This limit was set after discussions with the Medical Research Council had indicated that no short-term effects would be detectable following such a dose.

H4 Protection against inhalation of radioactive material which might give rise to internal dose was assured by the issue of respirators. In the event, apart from a very few restricted groups such as the Indoctrinees at Operation BUFFALO and the Active Handling Flight, the hazard from airborne particulates was minimal during all the UK atmospheric nuclear trials.

H5 For Operation TOTEM the same dose limits were used as for Operation HURRICANE. It was formally stated that the maximum permissible levels for inhalation, ingestion and skin contamination would be the same as those in force at AWRE.

H6 New recommendations as to maximum permissible doses were made by the ICRP in 1955. These were followed by AWRE in all subsequent trials. The new Normal Working Rate was changed to 1.5 rep per week of which the gamma component was not to exceed 0.3 roentgens. In the case of the Lower and Higher Integrated Doses, the period of non-exposure following was changed to that required to bring the mean weekly dose down to the same as the Normal Working rate. In addition,

a new Special Higher Integrated Dose of 75 rep was proposed, the gamma component of which was not to exceed 25 roentgens. Application of this Limit could be authorised only by the Commander of the Operation, after consultation with the relevant medical and Health Physics authorities. Exposure to the Special Higher Integrated Dose would debar the individual from exposure for a period of at least three years.

H7 It was explicitly stated that the number of persons exposed should be strictly limited and that all doses should be as low as practical.

H8 In 1958 the ICRP recommended new limits which were in effect one-third of the previous levels. In addition, it was explicitly stated that both stochastic and non-stochastic (present day term deterministic) effects should be taken into account in radiation protection. The new limit for whole body, blood-forming organs, gonads and lens of eye was 5 rem per year mean after the age of 18 (i.e. maximum total dose to be 5(N-18) rem, where N was the age of the individual) or 3 rem per 13 weeks. The limit for skin and thyroid was 30 rem per year and 8 rem per 13 weeks. The limit for any other single organ was 15 rem per year and 4 rem per 13 weeks.

H9 The 1958 limits were not published until the GRAPPLE series of trials and finished, but they remained in force during the post-trial clean-up Operations at both Maralinga and Christmas Island.

H10 The following are the significant safety instructions that were issued in the period 1953 - 1966 relating to air sampling and active aircraft handling. Copies of all these documents are held by ADS(HE).

1. Radiation Dosage - Operation TOTEM
Letter [redacted] with reply
11 February 1953

2. Operation TOTEM Radiological Safety Orders
Issued by [redacted], Scientific Superintendent
14 August 1953

3. Safety Levels for Contamination from Fallout from Atomic Weapons Trials
Health Physics Memo 6/55
Recommendations by [redacted]
Undated

4. Maximum Permissible Doses for Weapons Trials
Recommendations by [redacted], Superintendent Health Physics
April 1955

5. Safety on Weapon Trials
Health Physics Branch Memo 1/56
Issued by [redacted]
1956

6. Operation BUFFALO
Radiation Safety Regulations
Issued by [redacted], Group Leader Health Physics
Undated

7. Instructions to Escorts with Consignments of Radioactive Stores
Appendix B to RAF/AWRE/TS.1272
Issued by RAF/AWRE
26 June 1956

8. Air Task Group BUFFALO Operational Standing Orders and Instructions
Issued by [redacted], OC Air Task Group BUFFALO
31 August 1956

9. Radiological Safety Regulations for Operation GRAPPLE
First (Provisional) Edition
Issued by the Director AWRE
Undated

10. Operation GRAPPLE - the Operational Phase
The Joint Operational Plan Part 7
The Radiological Safety Plan
Issued by HQ Task Force GRAPPLE
1 March 1957

11. Operation GRAPPLE - the Operational Phase
The Joint Operational Plan Part 10
The Evacuation Plan
Issued by HQ Task Force GRAPPLE]
1 April 1957

12. No 160 Wing Standard Operating Instructions

No. 1 Terminology

No. 2 Cloud sampling

No. 7 Procedure for entering and leaving the active area

No. 8 Procedure for refuelling contaminated aircraft

No. 10 Procedure for leaving and re-entering active aircraft

Issued by [redacted] AOC No 160 Wing RAF
May 1957

13. Operation GRAPPLE X
Personnel Safety Plan
Issued by HQ Task Force GRAPPLE
20 October 1957

14. Health Physics Instructions

No. 1/58 Second line servicing of contaminated aircraft of 76 Squadron

No. 2/58 First line servicing of contaminated aircraft of 76 Squadron

Issued by [redacted], Health Physics Officer
RAF Detachment, RAAF Edinburgh Field
Undated

15. Radiological Safety Regulations Christmas Island RSRC/58(1)
Issued by the Director AWRE
March 1958

16. Shipment of Radioactive Stores
Issued by [redacted] AWRE Liaison Office
Maralinga Project Office, Adelaide, Australia
4 March 1958

17. Operation GRAPPLE Y
Personnel Safety Plan
Issued by HQ Task Force GRAPPLE
5 April 1958

18. HQ GRAPPLE Directive on the Control and Operation of Remedial Action as Required from X-60 minutes to Stand-down
Issued by HQ Task Force GRAPPLE
16 April 1958

19. Instructions on Precautionary Action to be Taken by Units Prior to D-Day
Issued by HQ Task Force GRAPPLE
21 April 1958

20. Health Control of Workers Exposed to X-Rays and Radioactive Materials
AM order A.129
Issued by the Air Ministry
23 April 1958

21. Personnel Safety Plan
Issued by [redacted], Senior Admin Officer
21 April 1958

22. Standard Operating Procedures for Cloud Sampling Operations

Instruction No. 1 Terminology

Instruction No. 2 Cloud sampling

Instruction No. 4 Particle sampling equipment

Instruction No. 5 Gas sampling

Instruction No. 6 Procedure for entering and leaving the aircraft decontamination area

Instruction No. 7 Procedure for refuelling contaminated aircraft

Instruction No. 8 Crash procedure for contaminated sampling aircraft

Instruction No. 9 Procedure for leaving contaminated Canberra aircraft

Instruction No. 10 Procedure for leaving contaminated Shackleton aircraft

Issued by [redacted], Air Task Group Commander
30 April 1958

23. Return to the United Kingdom of Contaminated Aero Engines
Issued by [redacted], RAF Detachment RAAF Edinburgh Field
May 1958

24. Radiological Safety Regulations Christmas Island RSRC/58(2)
Issued by the Director AWRE
July 1958

25. Operation GRAPPLE Z
The Air Plan Annex 5
Search and Rescue Standing Orders
Issued by HQ Task Force GRAPPLE
Undated

26. Personnel Safety Plan - Air Drop
Issued by HQ Task Force GRAPPLE
18 August 1958

27. Personnel Safety Plan - FLAGPOLE
Issued by HQ Task Force GRAPPLE
28 August 1958

28. Operation GRAPPLE Z Personnel Safety Plan BURGEE
Issued by HQ Task Force GRAPPLE
12 September 1958

29. Radiological Safety Provisions in Australia for Air Transport between AWRE and Maralinga of Specified Shipments of Radioactive Materials
Issued by the Commonwealth of Australia Department of Supply
March 1963

30. Radioactive Contamination of Aircraft
Code of Practice for the Protection of Persons Exposed to Ionising Radiations Arising from the Radioactive Contamination of Aircraft
Issued by the Ministry of Aviation
1966

APPENDIX J

The Active Handling Flight

J1 The status of the Active Handling Flight is not entirely clear. While it appears from the documentary record at AWE that it was a part of 76 Squadron; some ex-members of the AHF assert that it was an independent Flight reporting to the Task Force Commander. Whatever the true situation, it is clear that no Operations Record Book was ever raised, though many ad-hoc reports and other documents survive. It also appears that it was never regarded as a posting unit, so there is no confirmation in an individual's Service Record that he served with the AHF, though service with 76 Squadron is usually noted.

J2 A number of AWRE civilians also served with the AHF in an advisory capacity; these have not been noted here.

J3 The main source for identification of individuals that served with the AHF is therefore the dose records held by AWE. A tentative decision tree is;

a) Individuals should be identifiable with 76 Squadron

b) Where AWE Health Physics records list dosemeters in the order in which they were issued for local convenience as opposed to alphabetically, it is likely that members of the AHF are grouped together

c) Members of the AHF are likely to be among those with higher recorded doses

J4 Some members of the AHF can be identified with a high degree of confidence, particularly those who served at several Operations. For others there are degrees of uncertainty and it is unlikely that it will ever be possible to arrive at a definitive list.

Table 1 lists 103 individuals believed by AWE at the time of writing to be AHF members.

Table 2 lists 127 RAF personnel with recorded doses of 10 mSv or more. It is noteworthy that this includes only 15 from **Table 1**; most of **Table 2** are Officer sampling aircrew.

The only establishment table that has been found to date is that for Operation GRAPPLE, given in **Reference 42**. This is copied in **Table 3**.

[redacted]

TABLE 1

AHF Members (tentative)

Name	Rank	Service No.	N.I. No.	Trials Attended*
[redacted]				

[redacted]

[redacted]

TABLE 1 cont.

Name	Rank	Service No.	N.I. No.	Trials Attended*
[redacted]				

[redacted]

TABLE 1 cont.

Name	Rank	Service No.	N.I. No.	Trials Attended*
[redacted]				

TABLE 2

RAF Personnel with recorded doses of 10 mSv or more

Name	Rank	Service No.	N.I. No.	Trials Attended*

TABLE 2 cont.

Name	Rank	Service No.	N.I. No.	Trials Attended*

[redacted]

TABLE 2 cont.

Name	Rank	Service No.	N.I. No.	Trials Attended*
[redacted]				

[redacted]

Key:

A	ANTLER
B	BUFFALO
EF	Edinburgh Field
G	GRAPPLE
GX	GRAPPLE X
GY	GRAPPLE Y
GZ	GRAPPLE Z
H	HURRICANE
M	MOSAIC
Ma	Maralinga
T	Totem

[redacted]

TABLE 3

Establishment of the Active Handling Flight at Operation GRAPPLE

	Flt Sgt	Sgt	Cpl/ Cpl Tech	J Tech	SAC/AC	Total
Aircraft Fitter	1					**1**
Airframe Fitter		1	1	1		**3**
Engine Fitter (S)			1	1		**2**
Airframe Mech (L)					2	**2**
Elect Fitter (A)			1			**1**
S[illegible]ace Worker					1	**1**
Elect Mech (A)					1	**1**
Inst Fitter (G)				1		**1**
Arm Fitter				1		**1**
Air Radio Fitter			1			**1**
Eng Mech (S) (T)					2	**2**
Aircraft Assts					4	**4**
Total	**1**	**1**	**4**	**4**	**10**	**20**

Reference 43 recommended an increase in this establishment of about 50%.

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45. ORB's for

No 22 Squadron
No 24 Squadron
No 49 Squadron
No 58 Squadron
No 76 Squadron (1)
No 100 Squadron
No 204 Squadron
No 206 Squadron
No 217 Squadron
No 240 Squadron
No 269 Squadron
No 543 Squadron

No 1325 Flight (2)

No 160 Wing (3)

RAF Christmas Island

No 32 Maintenance Unit

Notes:

1 Parts of this ORB are missing from the Public Records Office copy

2 ORB's are not usually raised for detached Flights. This appears to be an exception

3 No 160 Wing was the early designation for air units assigned to Operation GRAPPLE