Biological Effects of Radiation

Effect	Dose (rems)	
	If delivered over 1 week	If delivered over 1 month
Threshold for Radiation illness	150	200
5 per cent may die	250	350
50 per cent may die	450	600

For airbursts of weapons in the 0.5-1 Mt range, the area covered by 500 REM could extend for 2-3 kilometres downwind from the point of detonation.(41) For surface bursts, where radioactive material in particle form is drawn into the fireball from the earth, the 500 REM area could extend (assuming a constant average wind of 30 mph) about 100 miles downwind and nine miles across.

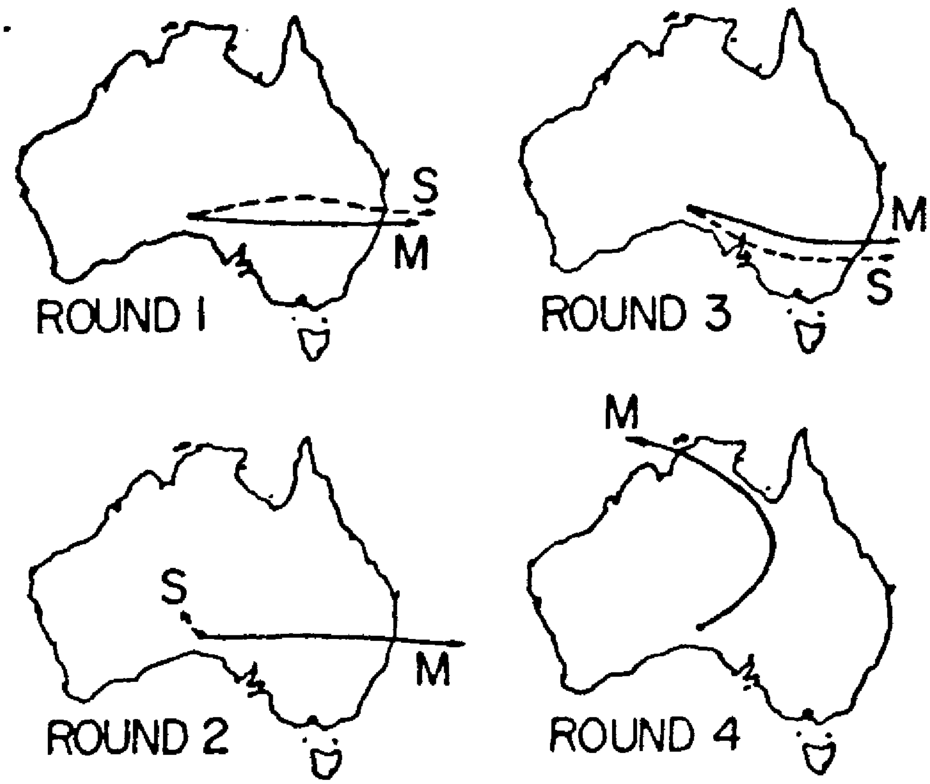
The general pattern of fallout distribution from nuclear detonations in some particular areas of Australia can be derived from the records of some of the nuclear tests that took place in Australia in 1952-57. The three test areas were Monte Bello, WA. (115.5 deg.E, 20.5 deg.S), Emu Field, SA (132 deg.E, 28 deg.S), and Maralinga (131.5 deg.E, 30.5 deg.S).(42)

ATOMIC BOMB EXPLOSIONS IN AUSTRALIA

1952 - 1957

Date	Location	Approximate size	Operation Code Name
3 October 1952	Monte Bello	Kiloton Range	
15 October 1953	Emu	Kiloton Range	
27 October 1953	Emu	Kiloton Range	
16 May 1956	Monte Bello	Kiloton Range	Mosaic
19 June 1956	Monte Bello	Kiloton Range	
27 September 1956	Maralinga	Kiloton Range	Buffalo
4 October 1956	Maralinga	Low yield	
11 October 1956	Maralinga	Low yield	
22 October 1956	Maralinga	Kiloton range	
14 September 1957	Maralinga	Low yield	Antler
25 September 1957	Maralinga	Kiloton range	
9 October 1957	Maralinga	Kiloton range	

The following figure shows the cloud trajectories of radioactive fallout from the four tests of Operation Buffalo, which took place at Maralinga on 27 September 1956, 4 October 1956, 11 October 1956 and 22 October 1956. All were relatively low yields. Rounds one and four were detonated on tall towers; Round two was exploded on the surface; and Round 3 was dropped from a Valiant bomber and detonated above the surface.(43)



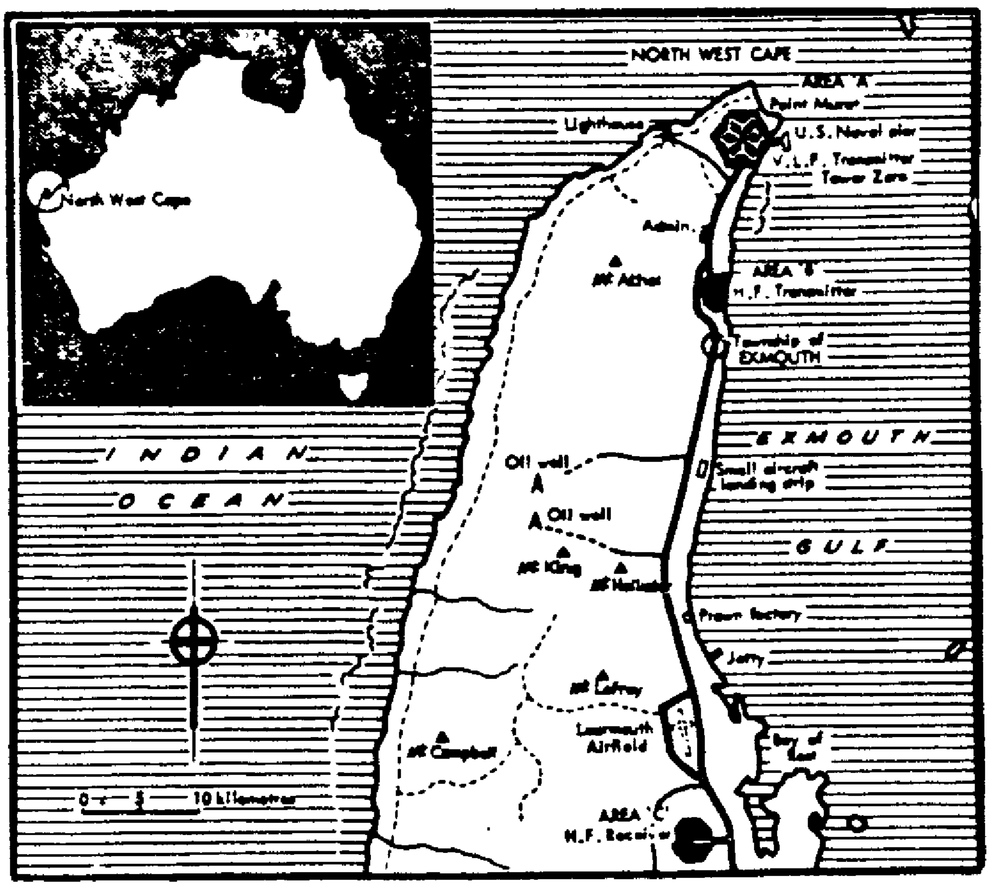
The cloud trajectories are shown for the four explosions. The path of the main cloud (M) is represented by a full line. When a secondary cloud occurred, its path (S) is indicated by a broken line.

Source: W.A.S. Butement, L.J. Dwyer, L.H. Martin, D.J. Stevens & E.W. Titterton, 'Radioactive Fallout in Australia From Operation Buffalo', The Australian Journal of Science, (Vol. 21, No. 1), July 1958, p. 65.

Great care was taken to ensure that the meteorological conditions were favourable at the time of the firings. Nevertheless, the secondary cloud from Round 3 on 11 October 'passed close to Adelaide and contaminated the city and surrounding countryside with radioactive fission products.' Minor contamination occurred as far as 1500-2000 miles from the Maralinga test site, with some significant concentrations of radioactivity found on the north-eastern coast and in central western Queensland. There was also some 'clearly discernible' contamination in the Alice Springs area.(44)

The three most likely targets in Australia - North West Cape, Pine Gap and Nurrungar - are fortunately located in relatively unpopulated areas far from Australia's major urban-industrial areas. Indeed, in terms of nuclear effects, the locations of these facilities are similar to those of the nuclear test sites of the 1950s - with an important caveat in each case: whereas none of the test sites were located close to any built-up areas, the VLF antenna at North West Cape is 20 km and the HF transmitter 5 km from the township of Exmouth (which has a population of just on 3,000); the Pine Gap facility is 20 km from Alice Springs (which has a population of over 16,000); and Nurrungar is 10 km from Woomera Village (which has a population of 3,000).

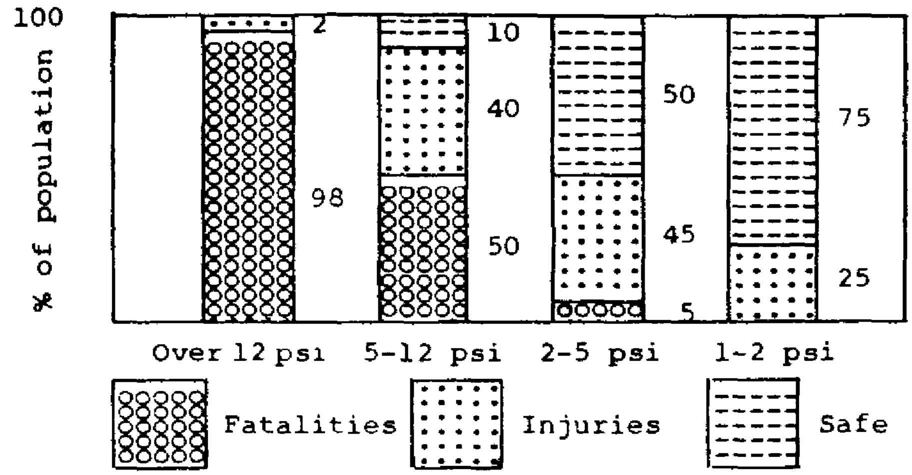
In the case of North West Cape, the desired ground zero (DGZ) would likely lie south of Tower Zero, calculated to not only ensure the destruction of the VLF transmitter but also to generate 1 or 2 psi over the HF transmitter.



RELATIONS BETWEEN PEAK OVERPRESSURES AND STRUCTURAL FAILURE

Structure or structural element	Damage	Approx overpressure psi
Glass windows	Shattering; occasional frame failures	0.5 to 1
Corrugated asbestos siding	Shattering	1 to 2
Corrugated steel or aluminum panel	Connection failure followed by buckling	1 to 2
Brick wall panel 8" or 12" thick (not reinforced)	Shearing and flexure failures	3 to 10
Wood siding panels standard house construction	Usually failure occurs at the main connections allowing a whole panel to be blown in	1 to 2
Concrete or cinder block walls 8" or 12" thick (not reinforced)	Shattering of wall	1.5 to 5.5
Wood frame building, residential type	Moderate: Wall framing cracked; roof badly damaged; interior partitions blown down	2 to 3
	Severe: Frame shattered so that for the most part collapsed	3 to 4
Wall-bearing masonry building apartment house type	Moderate: Exterior walls badly cracked, interior partitions badly cracked or blown down	3 to 4
	Severe: Total collapse of structure	5 to 6
Multistorey wall bearing building monumental type	Moderate: Exterior walls facing blast badly cracked, interior partitions badly cracked	6 to 7
	Severe: Some of bearing walls collapse	8 to 11
Reinforced concrete building, concrete walls, small window area	Moderate: Exterior walls badly cracked, interior partitions badly cracked or blown down, frame distorted, spalling of concrete	8 to 10
	Severe: Walls shattered, incipient collapse	11 to 15

VULNERABILITY OF POPULATION IN VARIOUS OVERPRESSURE ZONES



Source: Office of Technology Assessment, US Congress, The Effects of Nuclear War (Croom Helm, London 1980)

For a 1-Mt Weapon, this would generate 1 psi over the township of Exmouth - sufficient to shatter windows and cause occasional failures at the joints of panels in standard house constructions, but not sufficient to cause the collapse of standard residential houses.(45)

In the case of Nurrungar, a 1-Mt Weapon detonated over the facility would generate about 2 psi over Wommera Village - sufficient to cause the wooden frames of residential-type buildings to shatter so that the buildings collapse and to cause the ignition of some local fires.

In the case of Pine Gap, the blast effect at Alice Springs would be less than 1 psi. Some windows would break and there would be occasional frame failures, but most houses would be undamaged. The casualties from blast effects should be nil.

Concern has sometimes been expressed to the effect that a warhead aimed at Pine Gap could miss the target and hit Alice Springs, or at least impact such that the built-up area of Alice Springs lies within its lethal radius. However, the probability of such an impact is infinitessimal.

Assume that the distribution of warhead impact points is circular normal about the target point or DGZ. This means that errors in any two directions at right angles through the target point are independent of one another, but their extents are determined by the same probability distribution, ie the normal distribution:

$$P(x_0 < x < x_1) \propto \int_{x_0}^{x_1} \exp(-x^2/\sigma^2)\,dx$$

The parameter σ is directly related to the accuracy of the missile; the smaller σ, the more accurate the missile, that is, the less likely large errors are. In strategic literature, reference is usually made not to σ, but to the quantity 1.1774 σ, since this distance, the CEP, is such that the probability of the distance between target and impact being <u>less</u> than the CEP is the same as the probability of its being <u>more</u>, ie, each 0.5. Thus a disk of radius CEP with centre at the target will contain the impact point of, on average, one shot in two.

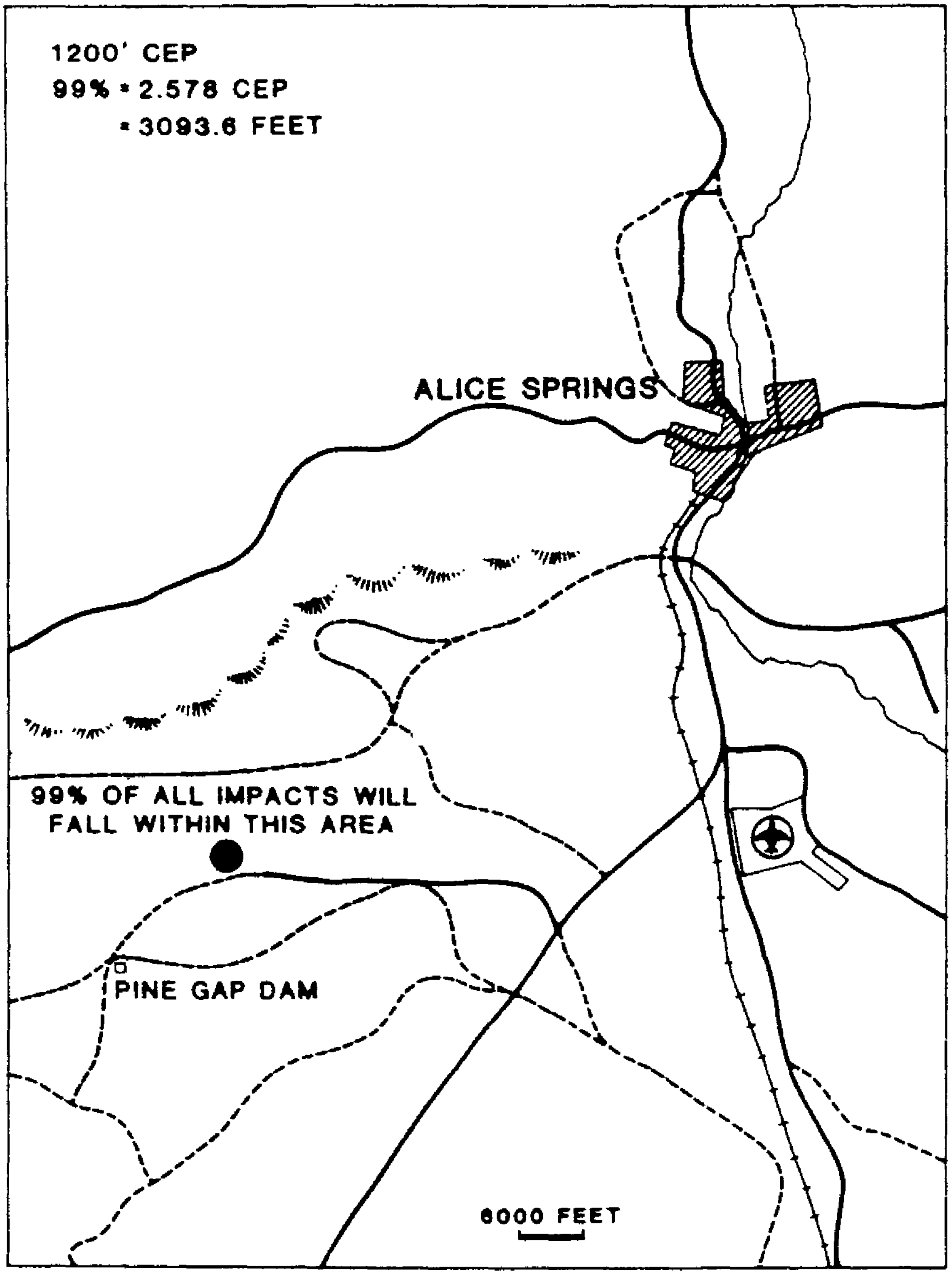
It follows from the normal distribution that 99 per cent of impacts will lie within a circle of radius 3.035 x σ, which is 2.578 x CEP (σ =0.8493xCEP and CEP=1.1774x σ). Thus the chance of an impact more than 3 CEP from the target point is negligible (<< 1 per cent).(46).

<u>Radius of P% Probability Circles</u>

P	σ	CEP
50	1.77	1
75	1.665	1.414
90	2.146	1.823
95	2.448	2.079
99	3.035	2.578

The built-up area of Alice Springs is about 10 n.m. from Pine Gap at its closest point. For the 5 psi contour of a 1-Mt Weapon to touch this area the Weapon would have to impact closer than 2.5 n.m., i.e. more than 7.5 n.m. from Pine Gap. In the case of the 25 psi contour, the impact would have to be closer than 1 n.m. from the built-up area, or more than 9 n.m. from Pine Gap. Given that 1200 feet is a representative CEP of the Soviet delivery vehicles, this means that to generate 5 and 25 psi at Alice Springs a 1-Mt Warhead would have to impact 38 and 45 CEP from Pine Gap respectively. From the normal distribution, the probabilities of this are 10^{-400} and 10^{-600} respectively! And, of course, if a missile was to land some 38 or 45 CEP from Pine Gap, it is just as likely to be to the south or west of the facility rather than the north-east, so that the probability of its lethal radius actually intersecting Alice Springs would be several factors smaller than these probabilities.

The casualties induced by blast effects from attacks against North West Cape, Pine Gap Nurrungar are therefore likely to be extremely low indeed - excluding, of course, those employees working at the three facilities at the time, which would total about 500 people.(47) However, there could well be casualties resulting from fallout, depending on such factors as the number, size and fission fraction of the weapons used; whether they are detonated in the air or on the ground; the prevailing wind patterns and other meteorological


1200' CEP
99% = 2.578 CEP
= 3093.6 FEET
ALICE SPRINGS
99% OF ALL IMPACTS WILL
FALL WITHIN THIS AREA
PINE GAP DAM
6000 FEET

conditions at the time of the attack; and the civil defence measures available (most particularly, the effectiveness of evacuation plans and the nominal protection factors (PF)).

The direction and strength of the prevailing winds vary according to the season and the time of the day.(48) At North West Cape the winds are generally from the south, so that any fallout generated by an explosion at the VLF and/or HF transmitter sites would blow away from the township of Exmouth; in Central Australia the winds are generally from the south-east, so that fallout from any attack on Pine Gap could well blow over Alice Springs; around Nurrungar, the winds are much more variable, with northerlies generally prevailing in the winter and southerlies in the summer. Adelaide's winds during the winter are frequently from the north and north-west, so that it could well receive fallout from explosions at Pine Gap or Nurrungar during that season. The worst case situation for Adelaide would be an attack against Nurrungar which involved a ground burst at a time when the winds were north-westerly and blowing at more than 30 kph (which is quite common in winter), in which case the radiation level in Adelaide would be about 50 to 100 REMs - sufficient to cause nausea and lower resistance to other diseases, and to cause some long-term damage, but medical treatment would probably not be required. Under the same conditions, however, (ie a 1-Mt ground burst at a time of north-westerly winds), the radiation level over such cities as Port Augusta (population 16,000), Whyalla (32,000), Port Pirie (15,000) and surrounding areas would be about 300 REMs, which would kill about 10 per cent of those exposed (49) - ie perhaps more than 10,000 people.

The second category of somewhat less likely targets consists of the bases at Cockburn Sound and Darwin. Although the probability of these being attacked is relatively low (say 20-25%, which in the case of Cockburn Sound is the likelihood of a US nuclear hunter-killer submarine being in port), the consequences of such attacks would be much greater than in the cases of North West Cape, Pine Gap and Nurrungar.

In the case of Cockburn Sound, a 1-Mt Weapon detonated in the air above HMAS Stirling on Garden Island, WA, would generate blast overpressures of 5 psi out to about 22,500 feet or 6.86 km, 3 psi out to 30,000 feet of 9.14 km, and 1 psi out to 60,000 feet or 18.3 km. The 5 psi contour intersects the mainland only at Cape Peron, which is a non-residential area. The 3 psi contour, within which wooden houses would collapse and some small fires would be ignited, includes much of the residential areas of Peron, Rockingham and Kwinana. The 1 psi contour, within which there would be some slight damage to residential houses, extends up to South Fremantle. Fallout is likely to be a much more serious problem than blast damage, particularly if a ground burst is involved. The afternoon winds over Perth and Fremantle are predominantly south-westerlies throughout the year. A 1-Mt ground burst at a time of such winds would deposit a radiation level of more than 1000 REMs over a narrow but elongated area of Perth and Fremantle, which would kill everyone exposed to that dose. A larger area would receive several hundred REMs, sufficient to kill 50 per cent of the exposed population. The total fatalities in this worst case situation could well be as many as 100,000 people.

In the case of Darwin, a 1-Mt Weapon detonated in the air above the RAAF Base would envelope the whole of the built-up area within the 3 psi contour and large areas would receive much higher blast overpressures. The fatalities from blast effects alone could well be as many as half the population (ie 25,000 people), with injuries suffered by a further 40 per cent (ie 20,000 people). Should a ground burst be used, which would more seriously damage the airfield runways while reducing the lethal radii of low blast overpressures against other buildings and equipment at the base, then much of Darwin would be covered with lethal levels of fallout.

The effects of attacks against the third category of possible targets - ie urban-industrial areas - are the most difficult to assess, precisely because of the relative implausibility of the relevant scenarios. For illustrative purposes, however, assume an attack on Sydney which involved a 1-Mt Weapon detonated on the ground at the GPO. In this case, the immediate fatalities (ie blast and heat) would number about 180,000, the fatalities from fallout would number about 480,000, and there would be about 350,000 injured people. The great majority of the population would be unaffected.(50) Similar results would attend an equivalent attack on Melbourne.

Warning Times

A critical consideration in any assessment of the effects of a nuclear attack and the effectiveness of measures designed to limit damage from such attack is the amount of warning time available. Measures designed to alleviate damage in situations where there is assumed to be no warning (ie a surprise attack out-of-the-blue) tend to be very costly, or relatively ineffective, or both.

In the United States in the 1950s and 1960s, it was assumed for planning purposes that if a nuclear attack occurred, the strike would be sudden and massive, leaving only the time after tactical warning for civilians to obtain protection.

For an attack against Australia, the tactical warning time could be anything from 5 to 45 minutes, depending on the locations of the specific targets and the type of delivery system used. The Code 647 DSP early-warning satellite controlled from Nurrungar is designed to detect the launch of an ICBM in the USSR from the infrared emitted by the rocket plume as the missile rises through the atmosphere. The Nurrungar facility would learn of any ICBM attack within 60-90 seconds of launch, which would provide some 40-45 minutes warning of any strike against Australia.(51) The warning time for an SLBM attack would be much less than this. In the case of the major Australian cities or installations located on or near the coast (eg North West Cape, HMAS Stirling, RAAF Base Darwin), the warning might only be 5-10 minutes. In the case of an SLBM attack against Pine Gap, the warning time would be about 15 minutes. This would provide sufficient time for any endangered populace to do no more than hurry to an existing shelter if one happened to be nearby. It is nor surprising that analyses based on the assumption of tactical warning only suggest the relative ineffectiveness of civil defence measures. This assumption alone can prevent the development of potentially much more effective protective measures.(52)

In the early 1970s, the US came to accept that a nuclear attack would not be made from out-of-the-blue but would be preceded by an international crisis, which in turn would provide from several days to several months of 'strategic warning': and in 1974 the Secretary of Defense issued SECDEF guidance to the effect that planners should assume that nuclear hostilities would be preceded by such a strategic warning period.(53)

The accompanying table shows a shematic nuclear crisis scenario.(54) The scenario is not intended to have any predictive validity, but only to illustrate a reasonable sequence of events in which a crisis takes more than a month to unfold and the first use of nuclear weapons takes place at least a week before there is any major strategic nuclear exchange.

A SCHEMATIC NUCLEAR CRISIS SCENARIO

Date	
1 July	East German uprising
5 July	Violence increases - West Berlin absorbed by East Germany
7 July	Intervention by West German units
9 July	Soviet Union 'ultimatum' threatens escalation (mobilizes)
12 July	Large-scale, conventional border clashes halted
15 July	Three-day cease-fire violated
18 July	Negotiations collapse, fighting resumes
22 July	Soviet Union troops advance deep into West Germany
28 July	Both sides use tactical nuclear weapons
1 Aug.	United States - Soviet Union exchange of ultimatums
3 Aug	Soviet Union strikes soft counterforce targets in United States (with an attempt to avoid much collateral damage) - and uses hot line
4 Aug	United States responds partial counter-force (also with avoidance) - and uses hot line
5 Aug	???

The notion that warning may be given by a pre-attack crisis suggests the possibility, or even the likelihood, that before an attack there might be weeks or even months during which normal peacetime civilian behaviour would no longer be expected. Warning of this kind, ranging from a few days to several months, would enable the preparation and perhaps even practice of plans for orderly evacuation and the procurement of materials for the construction of expedient shelters should that seem necessary. Such measures could reduce the earlier estimates of fatalities by a factor of 10 or more.

Damage Limitation in the Australian Context

The principal means of limiting damage to the civilian population are the evacuation of that population from possible target areas, and the provision of blast shelters and/or fallout shelters in areas likely to experience nuclear effects.

Evacuation of the population from possible target areas is potentially the most effective means of limiting casualties. Indeed, if the whole population could be relocated away from high risk areas then the casualties could be reduced to zero. Moreover, evacuation is relatively a very inexpensive operation. The preparation of evacuation plans, the regular (though infrequent) exercise of those plans, the salaries of a few hundred professional personnel trained to give appropriate local guidance, and the stockpiling of selected host areas with food, shelter materials, clothing and other minor supplies, would cost perhaps $3-4 million annually - approximately 0.1 per cent of the current defence budget. This figure would include evacuation planning for all the major Australian cities as well as the high risk areas around and downwind from the US facilities and Australian bases used by US forces. The former Commonwealth Directorate of Civil Defence has stated that 'plans are being prepared which will enable strategic evacuations to be made should the Government decide such movements to be advisable',(55) but the scope and practicality of such plans has never been revealed.

There are, of course, a number of major problems with reliance on evacuation. To begin with, there must be adequate warning time, which with regard to evacuation of the major cities such as Melbourne or Sydney would mean perhaps two to three days. Determination of the safest host areas is difficult because the direction the winds would blow after an explosion cannot be predicted with sufficient accuracy. The population must be either co-operative or at least non-resistant to the planned relocation - and this applies to the host population as much as to the evacuees. A capability for phasing smoothly into (and out of) an evacuation posture is essential: it could be managed with reduced costs (political, economic and sociological), it could reduce uncertainty about its success, it could result in improved fallout protection, and it could help solve the problems of supplying the evacuees in the event of a protracted crisis.(56) The avoidance of false alarms would be critical to the success of the operation, since it would probably be most difficult to persuade people to evacuate on the third or fourth occasion. This means that the evacuation planners must possess extremely fine judgement as well as having timely access to all relevant intelligence and warning indicators.

Fallout shelters are generally the next most cost-effective means of limiting casualties. There are three broad types of programs which could be considered: the provision of large public shelters in the major Australian cities and in the towns in the high risk areas; a program of private shelters at places of work and residence; and preparation for the construction of expedient shelters as the circumstances warrant.

The radioactivity associated with heavy fallout diminishes steadily with time, starting immediately after the explosion, by a factor approximately of ten every sevenfold increase in time. If, for instance, the dose rate one hour after the explosion were 1,000 roentgens per hour it would be 100 roentgens per hour at seven hours, ten roentgens per hour at 49 hours (say two days), one roentgen per hour at two weeks and 1/10th roentgen per hour at fourteen weeks (three months). (57)

The degree of protection provided by a fallout shelter or other shielding is known as the Protection Factor (PF), which is the reciprocal of the fraction of radiation that penetrates a given protective structure. In other words, if a building occupant receives one-tenth (1/10) of the radiation which he would have received had he been standing on a smooth horizontal plane outside the building with fallout evenly distributed everywhere around him, then his PF is said to be 10. A PF of three, which is provided by a single-storey brick house, means that the radiation within the house is one-third of that outside. A house basement may have a PF of 20 to 40 (reducing radiation to two and a half to five per cent of that outside) if it is completely below ground level. A cover of approximately two feet of dirt or 16 inches of concrete can give a PF of 50-100.(58) In Australia, the recommended minimum PF for public fallout shelters is 40, and for hospitals and public utilities which are expected to function through an emergency is it 100.(59)

A nationwide private shelter program, involving the construction of a small family fallout shelter at each occupied private dwelling in Australia, would be the most expensive approach to a fallout shelter program; it would also be a most inefficient approach, since most dwellings would be outside likely areas of radioactive contamination.

The cost of a nationwide private shelter program can be relatively low if the program is undertaken at a steady rate over a long period, with construction of particular sheltered areas (such as modified basements) being done at the time the buildings themselves are constructed. For example, the residential shelter construction program in Sweden is estimated to add approximately two percent to new residential building costs.(60)

The prices quoted for private backyard shelters manufactured in Australia range from $2,500 to $17,000, depending on their design and materials and on the amount of excavation required; $10,000 is perhaps an average price for both the shelter and its installation.(61) In 1976, there were some 4,140,500 occupied private dwellings in Australia - some 2,766,000 in the major urban areas, 856,000 in other urban areas, and 518,000 in the rural areas. A program involving all private dwellings in Australia could thus cost more than $40 billion.

The areas where such shelters could well make a significant difference to casualties include Alice Springs, Woomera Village, and the area to the south-east of Nurrungar (including Port Augusta, Port Pirie, and Whyalla). The construction of some 30,000 shelters in these areas could cost $300 million.

There are two major problems with implementing a private shelter program in Australia. First, since a nationwide system would obviously be both exorbitantly expensive and most inefficient, there is the problem of selecting the areas in which such shelters would be desirable. The process of identifying these areas could well have adverse political consequences. Second, there is the problem of enforcing any requirement for private shelters. Such shelters are compulsory in Sweden, Switzerland and Israel, but these countries have different political and strategic circumstances to those of Australia, and public compliance has not been readily forthcoming even in those countries. There is also a particular problem of enforcement in Australia in that any Australian program would more likely be selective rather than national.

The other two types of fallout shelter programs are expedient protective structures and large-scale public shelters. Expedient shelters are those which can be constructed from materials at hand within the likely period of strategic warning. Many expedient shelter designs capable of high PFs can be constructed with about 100-250 hours of labour.(62) These involve digging a hole some 350 cm (10-12 feet) deep) some 200 cm (6-7 feet) wide, and some 450 cm (15 feet long, covering this hole with brushwood fascines, and covering these in turn with a layer of compacted clay and then 70-80 cm (2-3 feet) of soil on the top. Such structures can house 10 to 20 people and would provide a PF of about 40.

Even simpler expedient shelters are possible. One type of shelter recommended in an emergency is a trench, a metre wide and sufficiently long to accommodate the members of a family, and covered with boards or doors removed from the house, and then covered in turn with a waterproof membrane and 60 cm (2 feet) of soil.(63)

The definition of a public nuclear fallout shelter used by the NDO is a structure having a PF of 40 or higher which is accessable to the public and which is able to accommodate a minimum of 50 people. The National Fallout

Shelter Survey has identified existing spaces in all suitable buildings in the capital cities, but neither the number of these shelters, their locations nor their capacity has ever been made public.(64)

Blast shelters are generally the least cost-effective of the range of possible damage-limiting measures, although they can be extremely valuable in certain specific situations. Most public blast shelters overseas are designed to withstand from 10 to 50 psi, although some Swedish shelters (eg the P-Klara shelter in Stockholm) can withstand as much as 150 psi, and to house from 500 to 5000 people. These shelters cost $4-6 per square foot, which includes the cost of the structure, earthworks, entranceway, environmental control system, and supplies for two weeks per person.(65) Assuming a constant space allocation of 10 square feet of gross floor area per occupant, a blast shelter designed for 5000 people would cost something like $250,000. On a normal work day, there are some 1.5 million people in Sydney within the 5 psi radius of the GPO (approximately 8 km, assuming a 1-Mt weapon) - ie an area of about 200 square kilometres.(66) The provision of 50 psi blast shelters throughout the central Sydney area would cut this risk area back to 6 square kilometres - and assuming a uniform population distribution would reduce the number of people at risk by perhaps 95 per cent. The cost of such a blast shelter system for these 1.5 million people would be approximately $75 million. A national blast shelter program would cost perhaps $0.5-1 b, depending upon how comprehensive it was intended to be.

The principal problem with such a program is that much of this expenditure would be wasted. A 50 psi shelter would not survive if it was closer than 1.5 km from the DGZ (assuming a 1-Mt Warhead), yet it would not be needed by people more than 8 km from the DGZ. In other words, it would be effective only within a narrow band around a given DGZ, but it would be impossible to predict a DGZ with any precision beforehand, and hence to properly locate the blast shelters within such a band.

However, there may be some particular centres or facilities which should be provided with some protection against blast effects because of their importance to the reconstitution of governmental authority in the aftermath of any attacks against Australia's urban-industrial areas. Many countries have implemented special measures for the protection of their National Command Authorities (NCA) and important elements of their leaderships. In Australia, an 1,800 square metre Crisis Command Centre is being built two floors underground at the new Parliament House site, although this was not especially designed as a blast shelter.(67) It might well be sensible to have shelters capable of providing blast protection for several thousand key personnel and critical communications systems.

The most appropriate posture for limiting damage from nuclear attack against Australia would probably involve some combination of evacuation, fallout shelter and blast shelter programs. The effectiveness of evacuation plans would be enhanced by the provision of some fallout protection for the evacuees, while some fallout and/or blast protection should be provided for those personnel responsible for city maintenance and high-priority activities.

CONCLUSION

The probability of nuclear attack against Australia must be assessed as being very low. Current developments in military technology and in the politico-strategic relationship between the United States and the Soviet Union are profoundly disturbing, but the prospect of large-scale urban-industrial destruction remains a powerful deterrent to any use of nuclear weapons by the superpowers.

However, while a strategic nuclear exchange is unlikely in the foreseeable future, it must be accepted that there would be targets in Australia should such an exchange nevertheless occur. The US facilities at North West Cape, Pine Gap and Nurrungar would certainly be targeted by the Soviet Union; the RAAF base at Darwin and the naval base at Cockburn Sound could be targeted in some circumstances; and there must be a finite although very small chance that Australia's major urban-industrial areas could be targeted.

The propositions that the US installations are the most likely targets in Australia, and that Australia would probably not be targeted in the absence of those installations, is frequently advanced in support of the argument that those installations should be removed. This would certainly effect a damage-limiting measure, but it is only one consideration in a very complex issue. It can be argued, for example, that insofar as the installations support surveillance and early-warning operations and communications for second-strike submarine forces then they are stabilising in that they reduce the probability of any Soviet first strike and hence of any strategic nuclear exchange.

In other words, although the presence of the installations greatly increases the probability of Australia being attacked in the event of a nuclear war, the operations of those installations could reduce the probability of war occurring in the first place. The actual likelihood of Australia suffering nuclear attack is a product of these probabilities. If Po is the probability of an attack on Australia in the absence of the installations and Pl its probability with the installations, and No the probability of nuclear war without them and Nl its probability with them, then the installations would be acceptable if Po No > Pl Nl, or

$$\frac{Po}{Pl} > \frac{Nl}{No},$$

where the decrease in the probability of nuclear war more than offsets the increased probability of Australia being attacked in the event of nuclear war.

260. Although some parts of Australia are likely to be attacked, the effects of this are not likely to be very great. It is a fortunate conclusion that the places which are the most likely to be attacked are located away from areas of significant population concentrations, while the probability of attack on the major urban-industrial areas must be reckoned as being very low indeed.

The casualties from blast effects of attacks on North West Cape, Pine Gap and Nurrungar would be essentially limited to employees working at these installations, but in some circumstances there could be significant fallout casualties, depending principally on meteorological conditions and on whether the weapons are air or ground-burst. The worst situation here would be a ground burst at Nurrungar with north-westerly winds prevailing. Attacks on the bases at Darwin and Cockburn Sound would be rather less likely, but the effects of these would be rather greater. Darwin could experience high casualties from both blast and fallout effects, and Perth and Fremantle could in some circumstances receive heavy doses of fallout. Australia's cities are most unlikely to be attacked, but in the event that they were, the fatalities could well exceed 1-2 million people.

The most appropriate protective measures depend on both the location of the possible targets and their likelihood of being attacked. Highly expensive shelter programs would be difficult to justify where the probability of attack is very low, as in the case of the major urban-industrial areas, or where the efficacy of such programs is sensitive to the vagaries of the meteorological conditions. Protection for certain key points, such as the National Crisis Command Centre, may be the extent to which it is possible to justify shelter construction. In general, the appropriate response may involve no more than the preparation of evacuation plans and the stockpiling of materials for expedient shelter construction, coupled with a program of public education on nuclear effects.

It is imperative, however, that there be some official acknowledgement of the facts that any nuclear war is likely to involve Australia, and that damage-limiting measures are by no means ineffective. Only then will it be possible for an informed debate to proceed on the most appropriate means of limiting damage to Australia in the event of a nuclear war.