STUDY OF PROTECTION OF THE AUSTRALIAN PUBLIC FROM IONISING RADIATION

LIST OF ATTENDEES

Mr J Allison	Materials Research Laboratory
Dr D Ball	Strategic and Defence Studies, ANU.
Mr J Barr	Executive Officer (Plans) Natural Disasters Organisation
Mr A J Beer	Director Northern Territory Emergency Service
Dr M E Bicevskis	Division of Public Health, Tasmania
Inspector B E Bingham	Operations Department, Victoria Police
Mr D H Brennan	SEO Strategic Policy Section (SP3) Department of Defence, Canberra
Mr J C E Button	Chief, Health & Safety Division, Australian Atomic Energy Commission
Mr K Cadee	Under-Secretary, Public Works Department WA
Brig N R Charlesworth (RL)	Executive Secretary, Royal Australasian College of Radiologists
Mr D Crancher	Chief of Division Australian Atomic Energy Commission
Dr A S Cumming Thom	Commissioner, Hospital Services, Health Commission, ACT
Mr M D Currie	Deputy Director, Victoria State Emergency Service
Dr D C Dawes	Deputy Medical Superintendent, Royal Perth Hospital, WA
Mr G A Deane	Principal Planning Officer, Co-ordinator General's Department QLD
Surg Cmdr K R Delaney RAN	Command Medical Officer HMAS Cerberus Department of Defence
Supt R E Dixon	Australian Federal Police
Mr J T Donnelly	Division of Public Health, Tasmania
Mr C H Ducker, MC	Director, Vital Installations, Protective Services Co-ordination Centre Department of Administrative Services
Dr J C Duggleby	Australian Radiation Laboratory

Mr R K Ellis	Assistant Director (Policy and Support) Natural Disasters Organisation
Cmdr J W Firth RAN	Staff Officer (Navy Plans) Joint Operations and Plans Division Department of Defence
Mrs J Fitch	Radiation Control Unit Health Commission SA
Mr A Fleischmann	Radiation Branch Health Commission NSW
Mr W I Hanna	Department of Transport and Construction
Mr D L Hill	Chief Operations Officer Western Australia State Emergency Service
Mr G Jukes	Department of International Relations Australian National University
Dr D Kelly	Medical Officer, Special Services Health Department, QLD
Mr B E King	State X-Ray Laboratory, WA
Dr W A Langsford	First Assistant Director-General, Public Health Division, Dept of Health
Mr J H Lewis-Hughes	Deputy-Director, State Emergency Service, NSW
Dr K H Lokan	Director, Australian Radiation Laboratory
Major G C McDowall	Australian Joint Warfare Establishment, RAAF, Department of Defence
Dr A C McEwan	National Radiation Laboratory Department of Health NZ
Mr J P McGilvray	Director, Division of Health and Medical Physics, Department of Health, QLD
Mr A Melbourne	Scientific Officer, Occupational Health Service, Health Commission, VIC
Mr R Nichols	Director. State Emergency Service, SA
Dr A F Nicholson	Defence Science and Technology Organisation, Department of Defence
Mr P R Patmore	Deputy Director State Emergency Service, TAS
Dr D W Posener	Scientific Adviser to NSW State Emergency Service and Civil Defence Organisation
Mr I A Prince	Department of Health, NT

Mr R E Rooks	Director, Emergency Service, ACT
Mr G Sabin	Bureau of Meteorology Head Office Department of Science and Technology
Dr C Smith	Counter Disaster Planning Health Commission SA
Mr T N Swindon	Australian Radiation Laboratory
Mr B Toner	Principal, Australian School of Nuclear Technology, NSW
Dr D B Travers	First Assistant Director-General Medical Services Division Department of Health
Dr R de C Tunbridge	Medical Consultant Health Commission, VIC
Major J S Wainwright	SO2 Medical Professional Services (Army Office) Department of Defence
Insp T J Whayman	OIC Search and Rescue Section Police Department, TAS
Mr K D Whiting	Director State Emergency Service QLD
Dr D W Williams	Research Scientist Materials Research Laboratory
Mr D J Withers	Public Health Division Commonwealth Department of Health

ANNEX B

AUSTRALIAN COUNTER DISASTER COLLEGE

STUDY OF PROTECTION OF THE AUSTRALIAN PUBLIC FROM IONISING RADIATION

8-12 NOVEMBER 1982

PROGRAM

Monday, 8 November 1982

6.00 pm Delegates assemble at ACDC

8.00 pm Background Briefing 1
Australia's Approach to Countering Disaster
- ACDC Staff

Tuesday, 9 November 1982

8.30 am - 10.30 am Background Briefing 2

Chairman: Dr Keith Lokan, Australian Radiation Laboratory (ARL)

* General Introduction - Dr Keith Lokan
* Reactor Accidents - Mr D W Crancher, Australian Atomic Energy Commission (AAEC)
* The Nuclear Attack Problem - Dr D Williams, Materials Research Laboratories (MRL)

10.45 am - 12.30 pm Keynote Address and Discussion

Mr Geoffrey Jukes - Department of International Relations, Australian National University

1.30 pm - 4.00 pm Discussion Exercise 1

'Identifying the Requirements for an Adequate Radiation Measurement and Assessment Capability'

4.00 pm - 5.30 pm Background Briefing 3

Chairman: Dr David Williams, MRL

* Arrangements to cope with Reactor and other Accidents involving Ionising Radiation - Mr J Button, AAEC
* Radiological Defence: Requirements for Radiation Measurement and Assessment - Some Overseas Arrangements - Mr J Allison, MRL

8.00 pm - 9.30 pm Background Briefing 3 (continued)

* Routine Fallout Surveillance - Mr C Duggleby, ARL
* Current Radiation Monitoring Equipment - Mr J Allison, MRL

Wednesday, 10 November 1982

8.30 am - 10.30 am Background Briefing 4

Chairman: Brig IGC Gilmore, ACDC

* A Case Study of COSMOS 954 - Dr K Lokan, ARL
* Emergency Treatment of Radiation Casualties - Surgeon Commander K R Delaney, RAN
* Contamination of Food and Water Supplies - Mr T Swindon, ARL

Wednesday, 10 November 1982 (continued)

10.45 am Background Briefing 4 (continued)

* Australia's Approach to Countering Terrorism
- Mr T H Mooney OBE
Assistant Secretary, Counter-Terrorism Branch,
11.30 am Protective Security Coordination Centre

11.30 am Discussion Exercise 2

'Meeting the Requirements for Protection of the Public against the threat of Ionising Radiation
5.30 pm Incidents'

5.30 pm Discussion Exercise 3

'Meeting the Requirements for Protection of the Public against the threat of Ionising Radiation
6.00 pm from Nuclear Attack'

8.00 pm

Thursday, 11 November 1982

8.30 am)
4.00 pm) Discussion Exercise 3 (continued)

4.00 pm Discussion Exercise 4

5.30 pm 'The Training and Public Information Requirement'

7.00 pm for 7.30 pm Seminar Dinner

Friday, 12 November 1982

8.30 am)
10.00 am) Discussion Exercise 4 (continued)

10.00 am) Review of Arrangements
11.45 am) Summary and Conclusions

11.45 am)
12.15 pm) Closing Address

1.15 pm Delegates disperse from ACDC

ANNEX C

AUSTRALIA'S RADIATION HAZARDS

Keynote Address by Mr G Jukes

Senior Fellow in the
Department of International Relations, ANU

The theme of this conference naturally compels me to attempt to look at the circumstances in which the public might be exposed to ionising radiation, and to leave it to the experts to say what is to be done about it if they are. Once one starts to look at possible 'scenarios', wider questions of public policy obtrude, and it would be unrealistic to shirk them. Australia is not a nuclear weapon power now, and is unlikely to become one in the foreseeable future. But it is allied to one nuclear power, the United States; it has a long historical relationship with another, the United Kingdom; friendly relations with a third, China; concern about the activities of France, which continues to test nuclear weapons in the South Pacific; and lively apprehensions about the Soviet Union. It is not in the business of generating electricity by nuclear power, and given its abundance of alternative power sources is unlikely to enter it in the near future; but it is linked with the international nuclear power trade because of its uranium deposits, which are something like 20% of the identified world total; while its acceptance of United States military facilities as part of its alliance commitment means that it cannot regard itself as immune from superpower confrontations and the risk of nuclear attack which underlies the diplomatic manoeuvring in which they engage. A third question concerns the hypothetical use or threat of use of nuclear weapons or materials in furtherance of the aims of terrorist organisations. There are therefore three types of contingency to be considered - nuclear industrial accident, terrorism or war. In discussing them, I am not implying belief in a high probability of any of them now or in the future. But even one in a million chances happen to somebody, and it is wise to insure against them if this can be done at reasonable cost, which I believe it can.

Take first, nuclear power stations, as the most remote source of accident; none either exist or are planned in this country at present, but I think that eventually we shall have no alternative but to follow the road taken even by resource-rich countries such as the USA, Soviet Union and Canada.

Nuclear Power

Every technological advance has aroused opposition, even when there was no generalised doubt about the benefits of advanced technology. There seems to me at the moment to be not merely a strong doubt in some sections of the public about the merits of a technology-determined future, but a certain tendency to grasp at the straws of alternative sources of power, particularly solar energy. While it can undoubtedly make a significant contribution, there are still considerable problems to be overcome in making it available on a commercial scale. It also seems to be forgotten that even when the technical problems are solved, as they undoubtedly will be, the large scale generation of solar power will require a great deal of land; its demands in this respect would be comparable to a quite sizeable agricultural program, and while this is not a problem in Australia it is liable to be quite a serious one in more densely populated countries where there simply is not the land to spare. The same is the case with hydro-electric power; some countries have an abundance of water that could be tapped for the purpose of generating electricity, while others do not. And while energy conservation measures can significantly reduce the demand, they cannot reduce it to vanishing point. It is also worth remembering that though the capital cost of nuclear power stations is high, the alternatives, including conservation, themselves often involve comparable expenditures. A public debate about nuclear energy will have to take account of the social and political dimensions of the problem, of concerns about risk and safety which are very present in the public mind, though not justified by the historical experience of the nuclear power industry so far, and should above all bear in mind that it is not sufficient for authorities to rely merely on publishing the data. In the early days of the Industrial Revolution, job preservation consisted of smashing machines. In the infancy of the steam railway it was argued that human beings would be unable to live, because they could not breathe at speeds of over 30 miles an hour, that livestock in the fields would be frightened into mass heart failures, and that accidents of horrendous proportions would be almost daily occurrences. As for the internal combustion engine, it was at its inception felt to be such a menace to life and limb that for a number of years all motor vehicles in the United Kingdom had to be preceded by a man on foot carrying a red flag.

Public fears should be treated with respect, not with the contempt of the expert for the laymen, but, even with the reduced expectations of expansion brought about by the recession, it has been clear for a number of years that fossil fuels are not an infinite resource, that burning them is not necessarily the best way to use them, given their rising cost and their utility for producing among other things plastics and agricultural fertilisers, and that alternative lifestyles, conservation, or renewable fuels are incapable of filling the gap between demand and supply especially for the developing countries.

The growth of nuclear power is inevitable; the connection which many people make between it and nuclear weapons is not, and this should be made clearer than it is; and while the absolute incidence of accidents inevitably grows with the scale of an operation, the relative incidence need not and usually does not, as long as the operation is conducted with due regard for safety. It has been pointed out in one of the background papers to this Conference that all bar an insignificant proportion of the fatalities which occurred in the nuclear industry are ordinary industrial accidents, equally likely to have occurred in coal or oil - or solar, or hydro-electric - installations, and that they compare very well with the fatalities incurred in mining or in the oil industry, processes which are an inseparable part of power generation using fossil fuels.

However, the complex of factors which so far have given uranium mining a worldwide safety record far superior to that of the coal industry, should not be taken for granted. The scale of the operation so far has been relatively small, because the quantities of ore to be shifted are far smaller than the amounts of coal, and, unlike coal, it has so far not been necessary to exploit low-quality deposits or ones which are especially difficult to get at. If in due course rising demand necessitates exploitation of the less attractive deposits, there will be an increase in occupational hazards from accumulated radioactivity both within mines and in the much bigger dumps of mine tailings. In the Australian context, in which uranium mining already goes on while power generation is for the future (and nuclear war hopefully is not), the question of mines and mine wastes cannot be left for more physical remoteness to take care of. Within the last three weeks New South Wales and the ACT have received from the sky substantial donations of Queensland topsoil: gifts of uranium mine tailings from the same source would probably be less welcome to Canberra gardeners, and in any event the substantial migrations of wind-blown soil are warnings of the extent to which fallout could spread if in a nuclear war the Soviet Union confined itself to attacks on US facilities in relatively remote areas.

A further point here concerns enrichment. Thermal reactors using natural uranium will be around for a long time yet, but enrichment from the naturally-occurring 0.71% of U-235 to between 3 and 6%, common for civil nuclear power reactors and necessary for the newer fast reactors is a more profitable export and creates more jobs. If job creation rather than mere quarrying is to be considered, and with the possible future domestic use of Australian uranium in mind, an enrichment plant is likely to be required.

Up to now it has been customary in Western countries to site nuclear power stations away from large population centres. This in fact about halves the economic effectiveness of the operation, because there is usually no means of utilising the waste heat in the cooling water. The Soviet Union and some of its East European allies are now going ahead with programs under which nuclear power stations will be sited in or near cities, and the cooling water used for district heating. It might be argued that this is merely another instance of disregard of the safety of their subjects by Communist regimes. But in the context of civil defence this is an almost impossible claim to sustain: the Soviet Union has in fact undertaken much more elaborate civil defence schemes than all bar a handful of Western countries, and it can be legitimately argued that in this connection they have shown more concern to protect their population than we have. But in any event, the Swedes have never been subject to the same doubts about their bona fides: and they unveiled a proposal five years ago for a nuclear power station with safety features which would enable it to be located under ground in the middle of a large city, doing all the things that the Soviet program will do, and very cost effective because its central location would not merely make it possible to utilise waste heat, but would economise to a large extent on transmission line costs. The idea of a nuclear power station as a potential nuclear bomb is a hard one to dispel, but it is likely to be eroded in time, especially with the development of smaller plants, the need for which was indicated some time ago. Given that power reactors utilise either natural or low-enrichment fuel, as opposed to the very highly enriched fuel used not only in nuclear weapons but in the reactors of nuclear propelled ships and submarines, that in normal circumstances they discharge no solid wastes into the atmosphere, and that reactor safety is already good and capable of further improvement, there are likely to be no compelling reasons for continuing to locate them only in remote areas.

They can be - and are - designed so that a serious accident can happen only if several unconnected malfunctions occur at the same time or in a particular sequence, and as Australia at present has sufficient alternative energy sources not to have to rush into nuclear power, it is likely that by the time this country embarks on nuclear power generation, reactor safety will be even more complete than it is now and the practice of siting the generating stations in remote areas will have been abandoned. There will then be a need for urban Civil Defence to be able to cope with possible emergencies, but organisational measures for casualty reduction in nuclear attack should be more than adequate to cover these also.

It is sometimes argued that because safeguards over nuclear material cannot be perfect, they serve no purpose and the only remedy is to stop the whole nuclear process. This argument seems to me to be sincere but misconceived - there are many stages between perfect control and no control at all, and I do not think that it has ever been seriously suggested that the only solution to the road toll is the total abolition of motor transport. Provided procedures are developed which not only keep the industry safe but are capable of dealing with the consequences of the inevitable occasional emergency, the nuclear power industry will continue to be, as it is now, less dangerous than other necessary components of industrial society whose hazards we take for granted and barely notice because we have lived with them for a long time. If we had one hundred large power generating reactors operating in this country now the chances of a worst-case accident would be approximately one in ten million per annum. Compared to the one chance in about four thousand five hundred that each of us stands of being killed in a car accident in the next twelve months, that amounts to no risk at all; it is certainly of no significance as an addition to the risks we already take for granted as a necessary trade-off for the other risks which have been reduced by technological affluence. Our remote ancestors did not have to worry about being killed by or in cars, about crashing in aircraft or being electrocuted, falling out of the windows of skyscrapers, having poisonous chemicals spilled in their vicinity, air pollution, or the risk of nuclear war. They were happily free of all these hazards, and the vast majority of them were dead before their fortieth birthday.

In the absence of totally reliable safeguards, the possibility of theft of nuclear material in quantities sufficient to make a bomb has to be faced. There have been various uncorroborated reports, for example, which suggest that Israel may have acquired material in this way; whether they are true or not, the possibility exists that enough material can be diverted or stolen over time to enable one or several explosive devices to be made. In the case of governments, the threat may well be containable, because governments and countries have a lot to lose, and no country which might threaten to use a small stock of weapons obtained in this way would be immune to counter-threats posed by, for example, existing nuclear powers with far greater resources. A combination of military threats and economic pressures could in most cases be used to 'contain' leaders who are not mad and, in the case of those who are, motivate their colleagues or their own military to remove them.

The situation with terrorists is otherwise. First, the terrorist by definition has opted for violence and if not naturally endowed with indifference to consequences, has cultivated it, especially where the consequences to others are concerned. Second, the terrorist is not necessarily confined to bringing pressure directly on his adversaries, if only because they of all possible targets are the most likely to be ready and waiting with counter-measures. That a country may have no connection with the terrorist's objectives does not necessarily give it immunity, it merely ensures that it will be less likely to expect trouble. There was a period in the late 1960s and early 1970s when the Palestine Liberation Organisation turned to hijacking aircraft as a means of publicising its cause, and in 1970 it attempted a simultaneous hijack of four aircraft - Israeli, Swiss, British and American. Only in the Israeli case was it unsuccessful. The PLO has long abandoned terrorism directed against non-Israelis, (though fringe Palestonian groups have not) but could revert to the tactic if no political settlement is found, and there are in any event numerous other groups of both right and left with no ideological objection to the dramatised use of violence, directed against countries and persons who have no direct connection with the issues which agitate them.

The techniques required to fabricate crude nuclear devices are a matter of public knowledge, and the main reasons why no case of 'nuclear terrorism' has yet occurred are:

a. that weapons-grade uranium (which is enriched to 90% or more of U-235) is produced only by complex and time-consuming enrichment techniques, (1-2 years by gaseous diffusion, though centrifuge processes are likely to reduce this to a few days), that these techniques are not

a. (continued)

available to amateurs, and the product plays no part in the international fuel reprocessing cycle, so that opportunities for diversion are limited.

b. that plutonium, though present in spent reactor rods sent for reprocessing, and therefore more liable to diversion than U-235, is extremely toxic even in very small amounts, so it is very difficult to handle; a terrorist who stuffed some in his pocket and ran would not get very far. It is not, however, totally inconceivable that a terrorist movement with the clandestine support of a maverick government could smuggle a device into a city and use that city as a 'hostage' against the fulfilment of its demands. The very toxicity of plutonium also means that even the threat to disperse a few grams into the atmosphere of a city, for example by aerosol, would have to be taken very seriously; the risks to the amateurs who assembled either bomb or aerosol would be immense, but most terrorist movements have at least some members who would be prepared to take them. As in the case of a nuclear power accident, measures taken to minimise casualties in nuclear war would be adequate to cover this contingency also.

<u>Nuclear War</u>

Australia's involvement in the ANZUS alliance with the United States has resulted in the establishment of some American installations in Australian territory which are virtually certain to be nuclear targets in the event of an all-out war. Some have argued that because of this Australia should seek refuge in neutralism. The argument is a more finely balanced one than the partisans of either side of it would be prepared to admit, but is essentially a question of trade-offs rather than absolutes. On the one hand it does involve an increased risk for Australia. but the position is rather similar to that involving any potential hazard. What matters essentially is not merely whether or not there is an additional risk, but what that risk amounts to. If it increases the hazard of nuclear attack from nil to, today, one in a million or even one in a thousand, then it is probably acceptable. If it increases the risk to one in ten, then it probably is not acceptable.

We accept a chance of about 1 in 4,600 of being killed by or in a car during the next twelve months, but most of us adapt our behaviour to it by not walking in the middle of the road or driving dangerously. The acceptance of alliance obligations which include some additional risk, however small, of involvement in a nuclear war, would seem to call for similar adaptive behaviour designed to mitigate the possible consequences.

The historical record so far tends to suggest that the increase in risk is low, and is more than counter-balanced by the reduction in risk, also low at present, but not always so in the past, and more readily conceivable than nuclear war, of conventional attack, which the alliance with the United States affords. It is likely that over time the alliance will become less important to Australia's security, but for the short and medium term at any rate there seems little likelihood that either the United States or Australia will wish to abandon it. That being so, the small but foreseeable risk of involvement in a nuclear war will remain, and with it the possibility of mass exposure to ionising radiation. The questions to be faced are:

a. what form would it be most likely to take if it eventuated?

b. what counter-measures are appropriate?

c. what lead times do they involve?

d. what is the Civil Defence role? and

e. what steps should be taken:

(1) now and

(2) at a time of threat?

I am not sure I know enough about it even to attempt to answer these questions, but asking them might serve a useful purpose in persuading those with more knowledge to focus on possible answers. But to construct what the jargon calls a 'scenario' I would hazard a guess that the cities themselves would not be prime targets; the adversary's purpose would be to 'take out' Pine Gap and North West Cape as a minimum, and probably some other US facilities as well, but probably not anything in or near a major city unless our importuning of the US Navy to use Cockburn Sound is excessively successful, in which case the Perth-Fremantle area would suffer heavy collateral damage and casualties. For the rest of the population the main hazard would be windborne fallout. This is an insidious hazard because it is not visible, and one against which the average Australian house (single-storied, thin-walled, with numerous and large windows and no basement) provides only incomplete protection. But because it is windborne, it takes some time to arrive, and its direction can be predicted. A combination of advance organisation to ensure adequate monitoring of levels, advance instruction to householders on how to make at least part of the house habitable in fallout conditions, and warning on when to take cover and how long to stay there would at any rate considerably reduce the consequences of the 'least worst case' scenario. I am not competent to comment on how well we are currently equipped to meet this minimal nuclear attack contingency, but internationally we do not seem to compare well even in the mere identification of space which is suitable for shelter with the UK, USA or West Germany, let alone Sweden, Switzerland or the Soviet Union.

There is, of course, a problem of public apathy towards Civil Defence, brought about by a general human unwillingness to contemplate the unpleasant, compounded by the belief that either nuclear war will not happen at all or if it does we will all be dead. The latter belief is probably untrue even of the countries in the Northern Hemisphere which are densely populated and likely to be prime targets for nuclear attack by either side; it is therefore even less likely to be true of this country, which is remote from the main centres of conflict and would most probably be attacked only selectively to destroy specified targets on its territory rather than because its territory as a whole is a target, as is the case with many of the other members of the two major opposing alliances. It would seem only prudent to take steps to meet at least the 'minimal attack' scenario I have postulated. Many would argue that I have been too optimistic, and that the weight of attack, if it came, would be far greater, including at the very least the major capital cities' armed forces bases. But if we have not made provision for the minimal scenario, we have Buckly's chance of coping with the more-than-minimal ones which can be constructed.

A recent United Nations document has provided some thought-provoking data on what various nations spend per head per annum on their Civil Defence. Switzerland, Norway and Israel spend over 10 dollars; Sweden spends 9, and the USSR 8, Finland and Denmark spend 4, West Germany 3½ and the United States 50 cents - of course, with their population even 50 cents a head can buy quite a lot of Civil Defence. We have a territory about as large as America's, but a population only about twice that of Sweden, and the figures in another document in the same series indicate that we spent a bit under 5 cents per head in 1979, one-tenth as much per person as the USA, one forty-fifth as much as Sweden; and a quarter of what Canada spends per head. Even allowing for the fact that data of this sort does not always compare like with like, we appear to be pretty close to the bottom of the international league when it comes to funding precautions against something which we all hope will not happen but which will have very unpleasant consequences if it should.

There has as yet been no serious debate in this country about Civil Defence, and there probably should be. It has been argued by some in the United States that the Soviet Civil Defence program is a component in the strategic balance, and is even capable of upsetting that balance. I believe this view to be unrealistic, because the capacity of a nation to survive and 'win' in a nuclear war depends not merely on how many of its citizens it can keep alive but on how much of its industrial, agricultural, administrative and communications structure can be kept functional, and the answer under a major attack is 'very little'. I do not propose to go any further into that argument, because the rationale for Civil Defence is something even a total pacifist can approve, and arguments which attempt to link it to war-making capacity would only fog the issue, even if they stood up better factually than they do. Even a well-balanced, fully integrated and totally implemented civil defence system would be unable to prevent large numbers of casualties in a nuclear attack, even at the minimal attack level I have postulated for Australia. But without it those casualties would be even greater, and the hardships of the post-attack period much worse than they need be. The limited international comparisons I have made indicate that the sums we spend per head are tiny compared to most of our allies and potential adversaries. It is not my purpose to attack our defence program, but there does seem to be an element of disproportion between the abortive proposal to buy HMS Invincible, which would have cost every man, woman and child in this country $26.56 before even a single aircraft was bought for it (without which it would have all the long-range striking power of a Manly ferry) and the few cents a year devoted to Civil Defence programs, whose function is to minimise as far as possible the consequences of attack by weapons against which a thousand 'Invincibles' could do nothing.

ANNEX D

BACKGROUND BRIEFING PAPERS

BACKGROUND BRIEFING 2

GENERAL INTRODUCTION

by Dr K Lokan, Director, Australian Radiation Laboratory

This seminar is concerned with the topic of protection against ionising radiation in the event of a nuclear accident or explosion of such a scale that a civil defence response is required. We will not be concerned with minor incidents, even though these frequently attract enough attention to give the appearance of national catastrophes, but only those events for which there is a real risk of substantial damage to public health.

We shall see that there are two classes of events, which we need to consider. One of these is the major release of radioactivity from a nuclear installation following an accident. Although it is a very unlikely event, particularly in Australia which does not have a nuclear power program, we need to discuss it, and to have a planned civil defence response because the time scale for an adequate response is likely to be very short - certainly less than a few hours. The other is the deliberate detonation of a nuclear device as an explosive. In this case the release of radioactivity would be only one of a number of sources of hazard and loss of life. Direct blast effects, burns and secondary diseases in the aftermath of a nuclear explosion would all be more significant contributors to overall casualties than ionising radiation. The nature of a civil defence response would therefore be very different, and the presence of ionising radiation simply an unwelcome complication in a rescue and recovery exercise. This first background briefing session will be devoted to introducing these two types of nuclear disaster.

While it is not appropriate at this seminar to devote a lot of discussion to the effects of radiation, it is useful to provide a unit for radiation exposure, and to indicate its magnitude and significance. For present purposes it is sufficient for us to quantify radiation exposure in units of effective dose equivalent. That is, we express any exposure to radiation as the equivalent uniform exposure of the whole body which would produce the same degree of risk as the actual exposure being considered. In many cases - for example, external irradiation of the body by gamma rays from a plume of radioactive material passing overhead - uniform whole body irradiation is exactly what might occur. The concept however allows us to add together partial body irradiation of particular organs, perhaps irradiated by inhalation into the lung, or ingestion into the stomach, taking into account the organ sensitivity and the quantity inhaled, and expressing each in terms of equivalent whole body exposure. The unit of exposure is the SIEVERT (Sv), and Table 1 illustrates some sources of exposure and the corresponding levels in this unit.

TABLE 1 (1 Sievert = 100 Rad)

Source	Dose (Sv)
Natural background	0.001
Annual limit for occupational exposure	0.05
Threshold for observable tissue damage	$\sim$ 1
Median lethal dose	5
Cancer therapy (not whole body)	5-20

Table 1 suggests that there may be two types of radiation damage to be considered. Doses above about 1 Sv, delivered in a short time produce evident damage to tissue (for example, skin reddening). Doses of about 5 Sv will cause the death of about half of the exposed victims. Lower doses, delivered at low dose rates over a long time may produce delayed effects, such as leukaemia or other forms of cancer, which do not manifest themselves for 10 to 20 years, or genetic changes which only appear in subsequent generations. For radiation protection purposes, and the estimation of the effects of low level exposure on populations, we adopt the conservative assumption that the risk is directly proportional to total population exposure. The experimental evidence we have (obtained in all cases at high doses and dose rates) indicates that the risk of fatal consequences is about 10^{-2} per person Sv. That is if a million people were given an effective whole body exposure of 0.1 Sv there would be about 1,000 delayed casualties, of the types described above.

This risk factor by the way, is about equivalent to the delayed incidence of lung cancer arising from smoking about one and a half packets of cigarettes per day for a year. (It is quite a useful yardstick to remember that a year of natural background (0.001 Sv) is equivalent to smoking about 100 cigarettes.)

APPENDIX 2
TO ANNEX D

BACKGROUND BRIEFING 2

REACTOR ACCIDENTS

Address by Mr D Crancher

of the Australian Atomic Energy Commission

Introduction

In answer to the question whether various agencies made adequate preparations for an emergency and whether their responses to the emergency were satisfactory, the President's Commission on the accident at Three Mile Island stated in October 1979, "Our finding is negative on both questions". One of the major outcomes of this finding has been a considerable upgrading, within the last year or so, in the level of emergency response capability now provided in the USA against nuclear reactor accidents. The findings of the President's Commission also received considerable international attention and many other countries have reviewed, or are in the process of reviewing, their emergency response capability.

The President's Commission recommended that "Plans for protecting the public in the event of offsite radiation releases should be based on technical assessment of various classes of accidents that can take place at a given plant". In the context of this recommendation it is important to distinguish between accidents which have actually occurred and hypothetical accidents which, from theoretical considerations, are believed to be credible.

It is this later class of hypothetical accidents which it is generally believed should form the basis for emergency planning, since they determine the upper limit of consequences against which the public could reasonably expect protective action.

A thorough analysis of hypothetical reactor accidents is a major technical undertaking involving multi-disciplinary teams of physicists, engineers, metallurgists and chemists with adequate computing support. In this briefing paper I have attempted to highlight the main issues which influence or need to be considered in these analyses, drawing together some of the major conclusions. A brief review of major reactor accidents is also included for comparison.

Reactor Design

A simple explanation of the fission reactor is given in Attachment 1. Thermal reactors (i.e. those using a moderator) only need to be considered since these are the predominant type. The power level varies from a few kilowatts in research reactors to several thousand megawatts in the latest nuclear power reactors. Since the potential risk is inter alia also related to the power level, the range of emergency response capability needs to vary enormously for different types of reactors.

For safety assessment purposes it is convenient to separate a reactor plant into the following three divisions.

a. <u>Process Equipment</u>. This includes all the major components, systems and equipment necessary for normal functioning of the reactor plant to meet its purpose. Typically, it includes the core together with fuel elements, the control system, the primary and secondary cooling systems, and normal power supplies.

b. <u>Protective Systems</u>. These are systems or devices designed to prevent over-heating, melting or damage to the fuel from any fault in the process equipment or operator error. Typical examples are emergency core cooling systems, reactor fast shut-down (scram) systems, standby and emergency power supplies.

c. <u>Containment Provisions.</u> These are essentially structures or other provisions enclosing the reactor plant to limit or restrict the release from the site of radioactive material that might escape in the event of a failure in both the process equipment and the protective equipment.

Ideally, the three divisions should be structurally and operationally completely independent. In practice this is rarely achievable and a major objective in reactor design is to ensure that where cross-connections are unavoidable (e.g. power supplies) the probability of a common failure mode is kept as low as practicable.

<u>Quantity and Characteristics of Radioactive Materials in Reactors</u>

Radioactive materials produced in the operation of nuclear reactors include fission products, transuranics and activation products generated by neutron exposure of the structural and other materials within and immediately around the reactor core. The fission products consist of about 200 different kinds of isotopes (nuclides), almost all of which are initially radioactive. The amounts of these fission products and their potential for escape from their normal places of retention represent the dominant potential public risk from reactors. Radioactive fission products exist in a variety of physical and chemical forms of varied volatility. (Virtually all activation products and transuranics exist as non-volatile solids.) The characteristics of these materials show quite clearly that the potential for releases to the environment decreases dramatically in this order:

a. gaseous materials;
b. volatile solids; and
c. non-volatile solids.

For this reason, analysis of the fission products released in hypothetical reactor accidents, together with practical experience of actual accidents, emphasises the dominance of noble gases and volatiles, such as iodine, in emergency planning. Consideration of particulate materials, however, should not be completely neglected. For example, capability to determine the presence or absence of key particulate radionuclides will be needed to identify requirements for additional resources in an emergency. Table 1 provides a list of dominant radionuclides for each exposure pathway.

Basic Safety Objective

Even a small fraction of the total fission product inventory of a power reactor could present a serious public health hazard if released into the atmosphere. The basic safety objective is to ensure that fault sequences which might cause such a release are identified and that these faults are either eliminated or their consequences reduced to acceptable levels by appropriate attention to the three design divisions discussed earlier.

Fission products are produced at the rate of 1 gm per day per megawatt of fission power. The daily rate of fission product generation for a reactor such as HIFAR will accordingly be 10 gm and a power reactor such as Three Mile Island some 2½ kg. At normal operating temperatures the fission products are retained by chemical and physical bonding within the atomic lattice of the fuel. However, the degree of this retention is highly temperature dependent and at temperatures approaching the melting point substantially all the gaseous and volatile fission products will be released very rapidly, together with smaller fractions of the less volatile nuclides. The maximum fractional releases occur in the molten fuel. Typical release figures used by the US Nuclear Regulatory Commission for safety assessment of light water power reactors are:

Noble gas release from fuel (Xenon, Krypton)	- 100%
Iodine release from fuel	- 50%
Non-volatile solids release from fuel	- 1%

It is clear that the basic safety objective stated above can be reduced to the more specific task of identifying fault sequences which, without adequate protection or containment, would:

a. lead to overheating or melting of the fuel; and

b. provide an escape route to the environment for the released fission products.

Accident Scenarios

Besides presenting a health hazard, fission products also generate substantial power within the core through the absorption by the fuel and surrounding structural material of the beta and gamma energy emitted during radioactive decay. Hence, even after a reactor is shut down (i.e. made sub-critical) it continues to generate substantial heat for a long time. This is called decay heat. Cooling must be provided for weeks after shut-down in order to prevent serious overheating or even melting of the fuel. Fig. 1 shows typical decay heat generation rates for a thermal reactor after it has been in operation for some weeks.

Any fault which prevents the cooling of a reactor core at any time is a potential cause of overheating of the fuel and fission product release. There are three classes of reactor accidents with this potential and these are now described.

Loss of Coolant Accidents

The accident at Three Mile Island was of this type. They are usually associated with breaks in the coolant pipes: however, as the Three Mile Island accident clearly showed, there could be other causes such as relief valves failing to re-seat. It can be assumed that the reactor would shut down under these circumstances. However, because of decay heat the core would rapidly heat up and for water-cooled reactors, whether power or research, fission product release into the containment via the break in the coolant system would follow, at a rate depending upon the rate of loss of coolant. For large break sizes, volatile gaseous fission products could be released within minutes. Although the probability of such accidents is low (of the order of once in a thousand years for a major pipe break), because the consequences could be serious, protection is considered essential.

This protection takes the form of an automatic emergency core cooling system. If the automatic core cooling system functions as designed, a serious release of fission products would be prevented. Should the emergency cooling provisions fail to function, then substantial releases of fission products could be expected and reliance would have to be placed upon the containment to limit the release to the environment.

The release of fission products into the containment would be accompanied by a rise of pressure in the containment. Since no structure can be made absolutely leak-tight, the pressure would tend to drive fission products out, very slowly, into the environment. However, most containments have provisions to reduce this pressure (e.g. by internal water sprays or heat removal systems) and, as a rule of thumb, the overall leakage from the containment could be expected to be less than 1% per day of the total quantity of fission products in the containment. Hence a loss of coolant accident is characterised by the following sequential events:

a. loss of coolant - less than an hour·

b. core melt - release of fission products into

b. (continued)

containment - less than 4 hours;

c. release into environment - slow leakage over many hours-days.

An estimate of the probability of a contained core melt of this type for a power reactor is of the order of less than once in ten thousand years per reactor. A similar estimate would also apply to research reactors such as AAEC's HIFAR reactor.

Power Excursions

It is physically impossible for any nuclear reactor to undergo a nuclear explosion. However, all reactors carry excess reactivity (see Attachment 1, paragraph 3.b) which, if released in an uncontrolled manner, could cause a power excursion, the severity of which would depend upon the characteristics of the reactor. For this to happen there would have to be a simultaneous failure of both the control system and protective system (scram) and the probability of this is very low. Analysis of the consequences of transients of this nature without scram shows that most reactors have inherent characteristics (inherent feed-back mechanisms) which will terminate the excursion. For planning purposes it can usually be assumed that the consequences will be less severe than a rapid loss of coolant accident.

External Events

Possible external events which could damage a reactor to the extent of releasing fission products might include aircraft crashes, earthquakes, fires and explosions outside the plant site. Such events are specific to a site and the first line of defence is to adopt a siting policy which will ensure freedom from these hazards. If this is not possible it becomes necessary to analyse the risk and provide protection as necessary. For example, reactors are not sited on known active earthquake fault lines. This may not ensure complete freedom since severe ground shaking may still damage the plant. However, in addition to siting restrictions, nuclear reactors are designed to withstand ground motion from two levels of earthquake, designated the Safe Shut-down Earthquake (S2) or Operating Basis Earthquake (S1). The Safe Shut-down Earthquake (S2) is related to the most severe that might be expected to occur, based on the best available seismological data. A return period of once in ten thousand years might be used where the records are sufficient to allow such estimates to be made. The Operating Basis Earthquake (S1) is based on an event that would be expected to occur once in the lifetime of the plant. Nuclear reactors are designed to ensure that, in the event of the Safe Shut-down Earthquake, the reactor will be shut down automatically and all essential safety-related structures and equipment can be operated safely.

A similar approach is adopted against aircraft crashes. Analysis of fatal aircraft crashes shows that most occur within about 5 km of the end of runways and so every effort is made to keep reactor sites beyond this distance. (Lucas Heights is some 22 km from the end of the Sydney Airport north/south runway.) If this is not possible, the structural details of the reactor plant would need to be examined to determine if the facility had sufficient structural strength to withstand the consequences of a crash. In the USA, if the probability of a crash is greater than 10^{-6} per year, structural capability to withstand the crash (including fires) is generally required by the nuclear regulatory body.

Risks from Accidental Releases of Fission Products

"Risk" is a commonly used word that can convey a variety of meanings. In reactor safety technology, the term "risk" has been given a specific quantitative definition:

$$\text{Risk} \left(\frac{\text{consequences}}{\text{unit time}}\right) = \frac{\text{consequences}}{\text{event}} \times \frac{\text{event}}{\text{unit time}}$$

Accordingly, in determining risk from reactor accidents, both their consequences and frequency of occurrence have to be considered.

The question of acceptable risks from nuclear reactor accidents is a societal matter, and currently no such limits have been established. However, the Nuclear Regulatory Commission in the USA has published possible risk levels from nuclear reactor accidents (called "quantitative safety goals") which it hopes will ultimately be acceptable to society. These proposals are given in Attachment 2.

Several detailed studies have been completed within recent years (similar studies are still under way) quantifying the risks from hypothetical reactor accidents (References 1 and 2). Table 2 summarises the results of these studies for a typical light water large nuclear power station (of the order of 3,000 MW thermal power output) of the PWR type. For reactors of smaller power level the risk will be proportionally less, assuming other features remain comparable, e.g. protection and containment. Hence the risk from a small 10 MW (thermal) research reactor such as HIFAR would be considerably less, possibly by several orders of magnitude. However, the fraction of the total fission products released into the atmosphere from a core melt will probably be similar for similar events in all reactors of basically comparable features, irrespective of whether they are power or research reactors. Table 3 suggests the possible order or fraction of release for two categories of severe accidents.

The role of emergency plans in reducing the exposure of people living downwind in the event of a serious reactor accident is important. The details of such plans are discussed in another paper. Most countries with nuclear power reactors have developed such plans, but the range of planning zones varies considerably between countries. Three examples for large nuclear power stations are:

United States	- 16 km for shelter or evacuation against inhalation from plume; 80 km for ingestion exposure pathways.
United Kingdom (plan currently under review)	- Evacuation and medical intervention up to 2 km; monitoring up to 40 km, mainly for ingestion.
Federal Republic of Germany	- Sites are selected on the basis of emergency planning as follows: 2 km, shelter evacuation, less than 3,000 inhabitants total and 1,300 per 30° sector; 10 km, detailed planning for evacuation - less than 8,000 inhabitants.

Review of Reactor Accidents

A summary of reactor accidents over the past 30 years during which fuel was damaged is presented in Table 4. Although several accidents have resulted in severe damage to the plant (e.g. Windscale, SL-1 and TMI-2), in no case has there been serious physical harm to the public and in no case has there been a need to evacuate the public because of high exposure. Evacuation of pregnant women and schoolchildren out to a distance of 5 miles was recommended during the course of the TMI-2 accident, but this recommendation was made because of the fear (unfounded) that the reactor accident could escalate.

The accidents at Windscale, England, in 1957, SL-1, USA, in 1961, and TMI-2, USA, in 1979, had major impacts on the subsequent course of understanding of reactor accidents and for this reason will be reviewed briefly.

The Windscale Accident - 9 October 1957, UK

The two Windscale reactors were natural uranium graphite moderated and cooled, used for the production of plutonium for military purposes. They were sited remotely on the north-west coast of England. During the course of a special graphite annealing operation to release stored energy (Wigner Energy), No 1 reactor overheated and eventually caught fire. The accident extended over several days and was eventually terminated safely by quenching with water.

Before this accident it was generally believed that fission products would be released in equal proportions. For this reason, fission products such as Sr-90, which was an important bomb fall-out nuclide, were considered the critical hazard. In the event, only about 2 Ci of Sr-90 was released. The total inventory of the noble gases Xe and Kr in the damaged fuel was released, together with about 12% of I-131. These nuclides were not anticipated and very rapid decisions had to be made during the course of the accident regarding emergency action levels for iodine.

Subsequent emergency measures centred around the monitoring of milk and its confiscation when levels exceeded 0.1 micro curies per litre.

The highest dose to a child's thyroid was estimated as 16 rads.

SL-1 Accident, 3 January 1961, USA

The stationary Low Power Plant No 1 (SL-1) was a small experimental natural circulation boiling water reactor sited on the National Reactor Test Site, Idaho, USA. The accident occurred during start-up of the reactor. A severe power excursion and steam explosion took place, killing two of the three operators.

The reactor building is best described as a "tin shed" that provided only limited confinement and no real containment; additionally, a fan provided 1.5 volume changes per hour from the reactor room to the atmosphere and a major access door was opened when the emergency response force appeared on the scene and it remained open for several hours. In spite of the lack of containment it appeared that less than 0.5 per cent of the I-131 inventory and a negligible fraction of the non-volatile inventory was found in the dry countryside. During the first 16 hours only about 10 Ci of I-131 escaped from the building to the environment. An additional 70 Ci is believed to have leaked out over the next 30 days. This low escape fraction is attributed to the presence of water, probable chemical form of iodine (CsI) and surface areas on which condensation could occur.

This accident again confirmed the dominance of iodine in reactor accidents. It also drew attention to the importance of limiting the reactivity investment in all coolant absorber, a lesson which is nowadays applied universally.

Three Mile Island, Unit 2, 28 March 1979, USA

The reactor in Unit 2 of the Three Mile Island power station is a pressurised water reactor capable of generating 880 MW of electricity. The unit had been placed in commercial operation only three months earlier and, at the time of the accident, was at 97% of rated maximum power.

The initiating event of the accident was a loss of feedwater to the steam generators caused by a tripping of the main feed pumps and subsequent failure of the auxiliary feedwater trains to come on line. The auxiliary feed pumps were inadvertently valved out and this was an infringement of the operating licence requirements. The plant was designed to cope safely with this contingency; however, an ensuing sequence of faults, some due to mistakes in operator judgment and some due to system malfunctions, caused a partial loss of coolant accident which, over the subsequent three or four hours, led to substantial fuel damage.

Substantial quantities of gaseous and volatile fission products were released from the core. Most remained contained within the reactor primary circuit and the containment building. The radioactivity which escaped into the environment was mostly Xenon 133 (5 day half-life), estimated at between 2.5 and 13 million curies (between 1½ and 9 percent of the total inventory). Small quantities of Krypton 85 and iodine were also detected. The escape of iodine was about 15.0 Ci, an amount barely detectable.

The maximum dose to any individual was 37 mrem and the population dose out to 50 miles was about 3,300 person-rems. Both the maximum individual dose (about the same as a short X-ray) and the population dose were small and physical effects were unobservable. The population dose led to the estimate of a fraction of one fatal cancer in the population of 2 million people within a radius of 50 miles. The psychological trauma to the public, especially local citizens, was severe and certainly not necessary. This was almost certainly due to the very poor management of the accident, which the President's Commission stated "... was dominated by an atmosphere of almost total confusion. There was lack of communication at all levels. Many key recommendations were made by individuals who were not in possession of accurate information ...".

Conclusion

Over 30 years' practical experience in operating nuclear reactors has now accrued and several accidents have occurred during this period. None of these accidents has caused serious harm to the public and there is no evidence that any member of the public has ever been killed. In spite of this good safety record, theoretical considerations show that accidents more serious than any that have so far occurred are credible and that it is prudent to have emergency response plans capable of reducing the number of potential casualties.

Emergency response plans need to be capable of being brought into operation quickly, possibly within an hour of a serious accident being confirmed. However, a matter needing careful consideration is the upper limit of accident severity for which the emergency response should be planned. There are no internationally agreed criteria on this matter and overseas practice varies considerably. As a basis for planning, it is suggested that emergency response should be capable of limiting exposures to below the emergency reference levels for evacuation for all hypothetical events with an estimated probability of occurrence of more than once in three thousand years.

References

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