



THE CBRN SYSTEM

Assessing the threat of terrorist use of chemical, biological, radiological and nuclear weapons in the United Kingdom

Paul Cornish



CHATHAM HOUSE

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February 2007

P.C.

EXECUTIVE SUMMARY

Introduction

In early November 2006 Dame Eliza Manningham-Buller, head of Britain's Security Service (known as MI5) warned that the danger to the United Kingdom of terrorist attack was 'serious' and 'growing', with as many as thirty terrorist plots under way. She argued that 'tomorrow's threat may – I suggest will – include the use of chemicals, bacteriological agents, radioactive materials and even nuclear technology'.

This paper draws upon material available in the public domain to address three questions:

- What are chemical, biological, radiological and nuclear weapons, and how available are they?
- What could terrorists do with CBRN, and why?
- How serious is the danger overall?

Chemical Weapons

Chemical weapons are usually described as *agents*, which can attack the body in various ways:

- 'nerve agents' such as sarin are highly toxic and attack the body's central nervous system;
- 'blood agents' such as cyanide prevent the absorption of oxygen by the blood;
- 'blister agents' such as mustard gas attack the skin and airways;
- 'choking agents' such as phosgene attack lung membranes.

In many cases, chemical weapon ingredients are 'dual use' in that they have legitimate non-military industrial applications. Many other industrial chemicals are also highly toxic, are relatively easy to acquire and would need minimal processing and preparation before use. Chemical weapons and toxic chemicals can be manufactured in solid, liquid or gas form, deliverable as powder, droplet or vapour by a variety of means including crop sprayers, smoke generators, artillery shells and aircraft munitions.

Chemical weapons have been described as 'the poor man's atomic bomb', an expression which also captures some of the moral and legal taboo which has historically (albeit not universally) been associated with chemical weapons. Although the large-scale production, weaponization and delivery of chemical weapons would be challenging, scientifically and logistically, as well as extremely expensive, a small number of low-yield chemical weapons would be relatively easy to hide and transport and might thus appeal to a well-organized and well-funded terrorist group. The public's vulnerability to lethal chemical weapons – particularly nerve agents such as sarin – has been apparent since the terrorist attacks in Japan in the mid-1990s. The fact that sudden death could come from colourless and (in some cases) odourless liquids and gases released covertly would add to uncertainty and could prompt panic. The possibility that a small-scale chemical weapon attack might trigger an immediate and disproportionately terrified response on the part of the target population could be seen by some terrorist groups as outweighing the difficulties, dangers and costs of developing chemical weapons.

Biological Weapons

Biological warfare agents comprise micro-organisms and toxins. Micro-organisms depend for their effect on survival and multiplication within a target body and can be both contagious (e.g. smallpox and Ebola) and non-contagious (e.g. anthrax). Biological toxins such as botulin are poisonous products of organisms, are inanimate and cannot reproduce themselves, and are intended to have effects broadly comparable to those of some chemical weapons. As with chemical weapons, a covert biological weapons programme could make use of easily available dual-use material and equipment, and could exploit the 'recipe books' which are reportedly available on the internet and elsewhere. Unlike chemical weapon manufacture, however, a bio-weapon programme might require only a small research, development and production process which would leave little or no signature and would therefore be easy to conceal. Although the weaponization of a biological agent would be complex, requiring high-level competence in microbiology, pathology, aerosol physics, aerobiology and meteorology, for a terrorist group seeking a 'single-shot' biological attack, safety, reliability and predictability in both production and weaponization might not be of great concern. Delivery of a biological weapon could be a relatively straightforward matter, with a variety of dispersal means available and with more than enough suitable targets on offer.

Biological weapons would be much easier to acquire or manufacture than nuclear weapons, and could have a bigger impact on public and political consciousness than chemical weapons. For these reasons, many argue that bio-weapons are becoming the terrorist's 'weapon of choice'. Although casualty estimates vary widely, the political, psychological and economic impact of a bio-terror attack would be profound, even in the event of a low-level or bungled attack.

Radiological Weapons

The purpose of radiological weapons (RW) would be to spread radioactive material over a wide area using either an explosive device, sometimes described as a 'dirty bomb', or some other means of dispersal. Depending upon the material used, individuals might receive high doses of radiation and the affected area (perhaps the financial district of a city) would be considered unusable until properly decontaminated. Radioactive material of various types can be acquired from a wide range of sources, including industry, hospitals and university research laboratories. Yet even though the use of these weapons could have serious political and economic consequences, the immediate effects of a RW attack would be limited.

Analysts are divided as to the effect of even a large-scale explosive RW attack, with some arguing that a victim close enough to the centre of the explosion to receive a serious radiation dose would be more likely to be killed promptly by the bomb blast than through radiation sickness. Yet while the physical harm from a RW attack might be limited, the blast could provoke panic and the prospect of radiological contamination could cause widespread anxiety. The assembly and handling of a radiological weapon would pose significant technical challenges to a terrorist group, and very severe health hazards. The technical challenges would not, however, be insurmountable.

Nuclear Weapons

A nuclear attack could be achieved in one of four ways.

- By acquiring and using a complete nuclear weapon. This is perhaps the least likely option, since stocks of nuclear warheads are generally closely supervised and the initiation of such a device would in itself be a complicated process.
- By building a nuclear weapon. This would require access to significant quantities of fissile material as well as other sensitive materials and components. High standards of engineering design and manufacture are necessary for successful construction of a nuclear weapon. But according to some analysts, these standards are becoming steadily more attainable.
- By constructing an Improvised Nuclear Device (IND) with much larger quantities of lower-grade, power reactor-quality uranium. The device might then 'fizzle' rather than detonate its entire mass instantly and efficiently.
- By attacking a nuclear power station, using conventional means (such as a large proximate explosion or the direct impact of a missile) to cause catastrophic breakdown of the reactor and its subsequent destruction.

The likely effects of a nuclear detonation are well known: blast, thermal flash and nuclear radiation causing vast numbers of deaths and very intense devastation over a wide area, together with an electro-magnetic pulse capable of destroying communications systems. It has long been supposed that use of a nuclear weapon would go so far beyond any notion of political violence as a form of negotiation that terrorists would not seek a nuclear capability. But thinking has shifted, and it is now feared that for terrorist individuals and groups driven by some religious, millennial or apocalyptic vision, the massive and hugely symbolic impact of a unilateral, 'spectacular' nuclear strike could be precisely their goal.

Conclusion

A well-funded terrorist group, particularly one with a long-term vision of conflict and with the intention to inflict as much damage as possible upon unprotected populations, might be attracted to the most sophisticated chemical, biological and nuclear weapons, in spite of the associated technical challenges. Even if only a remote possibility, the effects of such an attack would be devastating and cannot be dismissed as too remote to contemplate. But for some terrorist groups, the threshold of success might be much lower. At this level, the most basic chemical, biological and radiological weapons, and possibly even Improvised Nuclear Devices, could all prove tempting. It is appropriate, therefore, to think of CBRN as a *system*, offering all that might be required for a range of terrorist groups from the largest to the smallest, from the almost casual to the most organized, and from the poorest to the best funded.

1 INTRODUCTION

During the Cold War of the mid- and late twentieth century, military planners and weapon designers coined the term 'Weapons of Mass Destruction' (WMD) to refer to nuclear, biological and chemical weapons and their delivery systems (such as strategic bombing aircraft and ballistic and cruise missiles). Although analysts differed as to the merits of gathering all three, very different, weapon types under one umbrella term, WMD was generally understood to refer to special categories of weapons which could cause massive, overwhelming and perhaps even uncontrollable damage to life and structures, both societal and material. Particularly in the early years of the Cold War, some defence policy-makers and military leaders regarded WMD as simply weapons, to be designed, developed, deployed and used as such. But by the end of the East-West confrontation, the established view was that WMD occupied a unique, not to say peculiar field of security and defence analysis. The anticipated enormity of WMD use gave rise to a most unusual rationale for the development and deployment of any weapon system; WMD would effectively become extraordinarily expensive 'non-weapons' which could be designed, developed, deployed and threatened – but never used – in order to convince potential adversaries to exercise the same restraint.

The doctrine of mutual deterrence was complex, but for many it was inadequate as a means to prevent the spread and use of WMD, and possibly even contributed to that problem. Elaborate regulatory and policing arrangements were therefore put in place, designed to prevent the proliferation of WMD. As the Cold War progressed, powerful moral and political taboos were reinforced against the use of WMD, contributing to the widespread (albeit imperfect) sense of restraint surrounding these weapons. Biological weapons were banned by international agreement in 1975, while chemical weapons were prohibited by a convention which entered into force in 1997. The legal status of nuclear weapons remained much more equivocal, however. The 1996 advisory opinion of the International Court of Justice on the legality of the threat or use of nuclear weapons left open the possibility of legitimate nuclear use 'in an extreme circumstance of self-defence, in which the very survival of a State would be at stake'. There was a paradoxical quality to this outcome; the weapons which were considered to have the least value militarily (chemical and biological weapons – CW and BW), and were therefore least likely to be used, had been banned by international agreement, whereas nuclear weapons, which had always been considered militarily the most 'usable' of WMD (and therefore the most convincing in deterrent terms), retained their legitimacy.

When the decades-long stand-off between NATO and the Warsaw Treaty Organization came to an end in the early 1990s, the complex and esoteric rationale for WMD development rapidly lost the energy and authority it had once had. Since then, the argument that WMD should form part of a state's arsenal – whether as weapons *per se* or as a deterrent – has become progressively more difficult to make politically, strategically and morally. In the United States, recent ideas to develop either low-yield (and therefore more usable) so-called 'mini-nukes', or the 'nuclear bunker buster' or Robust Nuclear Earth Penetrator, have provoked controversy. Similarly, the debate surrounding the proposal to modernize the United Kingdom's submarine-borne nuclear deterrent has exposed high-level and widespread doubts about the rationale for such weapons.

If the Cold War rationale for WMD has all but vanished, the same cannot be said for the materials out of which they were built. For all categories of WMD, it has long been understood that much of the necessary technology and expertise is 'dual-use', having both military and civilian applications. In the absence of the Cold War military imperative, not only has genuine interest mounted in the civilian applications of WMD-relevant technology, but the illegal

proliferation of sensitive technology, materials and knowledge has proved both more tempting and more possible. In short, WMD technology has increasingly become something of a commodity since the end of the Cold War. The possibility that terrorist groups might gain access to this commodity has captured the imagination of security policy-makers, particularly since the attacks launched by al-Qaeda in the United States in September 2001. The received wisdom is that al-Qaeda, and other terrorist groups, would acquire and use WMD-related technology and materials if they could. However, a small and focused organization such as al-Qaeda seems highly unlikely to wish to emulate the behaviour of the United States and the Soviet Union during the Cold War, by acquiring vast arrays of the most complex and expensive weaponry ever developed. Instead, what such groups would seek is a terrorist effect from WMD-related technology; an effect which might be achieved with just one nuclear device, rather than thousands, or just a few litres of a manufactured toxin.

The possibility just described represents a particularly difficult challenge for security policy-makers, one in which WMD-related technology, materials and expertise have been commoditized, in which only relatively low levels of each will be needed to achieve the terrorist goal, and in which the motive to acquire such a weapon is to use it, rather than be drawn into some elaborate political dialogue. In these circumstances, the term 'Weapons of Mass Destruction', with all its Cold War connotations of massive effect and mutual deterrence, has largely given way to a new expression; 'Chemical, Biological, Radiological and Nuclear' (CBRN). CBRN is altogether a simpler, more descriptive term which not only incorporates a type of threat which was relatively unnoticed during the Cold War – the 'dirty bomb' or radiological weapon – but more importantly indicates a break from Cold War language and assumptions and allows attention to focus on a new and different adversary.

The purpose of this paper is to examine and compare each category of CBRN weapon and technology, in terms of the following criteria:

- Characteristics
- Availability
- Delivery Systems
- Consequences of Attack
- Utility
- Sample Scenarios

Each category concludes with a brief assessment of the likelihood of terrorist use.

This paper is driven by three observations. The first concerns the likelihood and consequences of a terrorist attack in the United Kingdom using CBRN, and the preparedness (often described as 'resilience') of all levels of UK government, the private sector and the wider public to meet such an assault. In early November 2006 Dame Eliza Manningham-Buller, head of Britain's Security Service (known as MI5), warned that the danger to the United Kingdom of terrorist attack was 'serious' and 'growing', and might last a generation. Manningham-Buller spoke of as many as thirty terrorist plots under way and argued that 'tomorrow's threat may – I suggest will – include the use of chemicals, bacteriological agents, radioactive materials and even nuclear technology'. For the head of the Security Service to make such a statement in public was unusual, and might be explained by the UK government's wish to improve national resilience by disseminating information about the CBRN threat. If so, this is a publicity campaign which must be very carefully managed. With too little information the public might be insensitive to the risks and might not be in a position to react in a measured, responsible and

constructive manner in the event of an attack. Conversely, if the public were to be deluged with information about possible terrorist scenarios, then an exaggerated and even paralysing perception of insecurity might set in. What is more, in the current climate if any information (particularly about security and defence) were perceived to have been 'managed' by government, then that information might be regarded as untrustworthy.

There is a strong case, therefore, for independent, balanced and above all accessible analysis of the terrorist threat to the UK using CBRN. There is a vast and ever-expanding open literature concerned with the technology, proliferation and effects of CBRN. Classified research and analysis has probably also generated its own sizeable word mountain; the scale (and urgency) of the international intelligence effort to track CBRN proliferation and to give timely warnings of possible or intended use can only be guessed at here. It is not the purpose of this paper to catalogue, review or synthesize the open literature, nor, even if it were possible, to complement or contradict classified research and analysis. The more modest goal, instead, is to draw upon some of the open-source literature (the source, after all, for most public perceptions of the CBRN danger) and other material to produce a series of scenarios with which to inform public awareness, following Manningham-Buller's warning that CBRN technology and weapons might be used in an attack.

This leads to the second observation, which is that a good deal of the effect of a terrorist attack in the United Kingdom using CBRN could prove to be self-inflicted by the victims of the attack – the general public, business leaders and government officials – or magnified by alarmist media. The United Kingdom might prove to be rather brittle in the face of a CBRN attack – there might be a demoralizing sense of defencelessness, particularly if unknown and invisible agents and pollutants are used, and possibly even widespread panic – and it seems reasonable to assume that terrorists might hope for such brittleness in order to expand the effect of their attack. The best preventive to such a response is, once again, a balanced understanding of the issues and the threats, and it is in such a spirit that this paper is written.

The third observation concerns the nature of the CBRN threat itself. CBRN weapons and technologies are all very different in complexity, construction, delivery and effect. This was tacitly acknowledged during the Cold War when although nuclear, biological and chemical weapons were all described as 'Weapons of Mass Destruction', some were regarded as more important and even useful than others. It is instructive at this point to consider the Cold War criteria for WMD: safe and reliable weaponization; robust construction to enable handling and deployment in a military environment, or even during conflict; decisive, accurate and predictable delivery; mass effect measured in many thousands of deaths and widespread physical devastation; and, finally, the need for all these qualities to combine to deter an adversary. The distinctive feature of international security in the early twenty-first century, however, is that terrorists can achieve the effect they desire using WMD-related technologies and materials which would barely qualify as a 'weapon' according to the Cold War criteria. A highly committed terrorist group could, conceivably, regard the risks associated with amateurish and unsafe 'weaponization' to be worth taking, and might regard 'handling' and 'deployment' as nothing more complicated than carrying a small bag into a crowded sports stadium. Accurate 'delivery' might be needed in some cases (e.g. symbolic targets such as public monuments or key buildings) but not in all; one part of a large crowd would be as good a target as another, and if sports stadiums were found to be inaccessible, shopping malls would offer substitute opportunities. The desired 'effect' might be no more than some hundreds or thousands of deaths, or the destruction of a few buildings, all of which would be magnified by the terrorist's 'propaganda of the deed'. As for 'deterrence', this seems likely to be the last

thing on the mind of the committed terrorist. With the threshold for success clearly so much lower for terrorist use of CBRN than for Cold War development of WMD, a still more important distinction becomes apparent. Whereas in Cold War strategic thinking neither biological nor chemical weapons were seriously considered to be a substitute for nuclear weapons, for the twenty-first century so-called 'expressive terrorist', CBRN offers four more or less equally viable routes to the desired conclusion. For this reason, this paper proceeds from the assumption that the acquisition and use by terrorists of chemical, biological, radiological and nuclear weapons should be understood and managed as parts of a whole – the 'CBRN system'.

2 CHEMICAL WEAPONS

Chemical Weapons: Characteristics

The use of chemicals and poisons as weapons of war is an idea with a lengthy pedigree, going back at least to 429 BCE, when the Peloponnesians reportedly used poisonous gases against the Spartans. Efforts to prohibit the use of chemical weapons are, on the other hand, a relatively modern phenomenon; the first international agreement to prohibit the military use of poisons was the Treaty of Strasbourg signed in 1675 between France and Germany, by which both parties agreed to prohibit the use of poison bullets. Chemical weapons arguably came into their own in the twentieth century, in terms of use on and off the battlefield, and in terms of regulation. The first major, industrial-scale use of chemical weapons was in April 1915, when the Germans released 180,000 kg of chlorine gas at Ypres. Thereafter, gas was used by the Italians in Ethiopia in the 1930s and by the Japanese in China before and during the Second World War. Most recently, chemical weapons were used by Iraq during its war with Iran, and against the Kurdish population of Halabja in 1988, killing some 5,000 people. There have been allegations of chemical weapon use in many conflicts around the world. The extremist cult Aum Shinrikyo used chemical weapons in Japanese cities in 1994–5. The development, production, stockpiling and use of chemical weapons are prohibited by the 1993 Chemical Weapons Convention (CWC).¹ The CWC entered into force in 1997, and now has no fewer than 162 states parties.

Chemical weapons are usually described as *agents*. Agents can be *persistent* or *non-persistent* and attack the body in various ways, both lethal and non-lethal:

- *Nerve Agents* (e.g. tabun (GA), sarin (GB),² soman (GD), cyclosarin (GF)), and *Thickened (or Persistent) Nerve Agents* including VX and Russian VX (RVX). Nerve agents act by 'switching off' the body's central nervous system. Nerve agents pose very difficult challenges in manufacture, weaponizing and delivery;
- *Blood Agents* (e.g. hydrogen cyanide (AC),³ cyanogen chloride (CK), and arsine (SA)). Blood agents prevent absorption of oxygen;
- *Blister Agents* (e.g. sulphur mustard,⁴ nitrogen mustard, phosgene oxime (CX) and lewisite). Blister agents attack the skin and airways, forming large contaminated blisters. Large quantities are required for a successful attack;
- *Choking Agents* (e.g. phosgene (CG)⁵ and diphosgene (DP)). Choking agents attack lung membranes, leading to pulmonary oedema;
- *Vomiting Agents* (e.g. adamsite (DM)). Vomiting agents cause a violent emetic reaction, which can be especially debilitating when used against troops wearing chemical protection equipment and masks, causing them to remove their protection and thereby expose themselves to other, lethal agents;
- *Incapacitants* (e.g. hallucinogens such as LSD and BZ, as well as sleeping and laughing gas);
- *Irritants* (e.g. tear gases such as CS,⁶ CN and CR).

Many other chemicals, sometimes described as toxic industrial hazards (TIH), are highly poisonous, relatively easy to acquire and require minimal processing and preparation before use. They include various acids, ammonia, chlorine, sulphur and formaldehyde. Pesticides can also be toxic to humans. Possibly the most celebrated case of mass TIH poisoning occurred in Bhopal, India in December 1984. Some 40 tonnes of methyl isocyanate (MIC) were accidentally released from Union Carbide's pesticide factory. In the first three days after the incident, over 8,000 people died in Bhopal, with a further 20,000 dying subsequently from illnesses related to

MIC exposure.⁷ As well as these liquids and gases, terrorist interest would also include the contamination of food and drink ('product contamination'), and the use of 'contact poisons' for assassination.

Chemical Weapons: Availability

Chemical weapons are often described as 'the poor man's atomic bomb'. Many of the CW precursor chemicals are 'dual use' in that they have civil industrial applications: mustard gas requires ethyl alcohol, sodium sulphide and bleach; thiodiglycol is used for ball-point pen ink, but is also 'only one chemical step removed' from mustard gas;⁸ the chemical ingredients for tabun (GA) are used in pesticides, those for sarin (GB) in flame retardants, those for soman (GD) in dairy and food-processing equipment, and those for VX in pyrotechnics.⁹ The US chemical industry produces some 1 billion kg of cyanide annually for industrial uses such as electroplating. The general availability of toxic and precursor chemicals has led to CW being described as 'the easiest of all catastrophic weapons to produce'.¹⁰ 'Easiest' although not 'easy': the production of CW remains challenging, scientifically and logistically. According to some estimates, Aum Shinrikyo's attempts to synthesize sarin cost as much as \$30 million, involved as many as 80 scientists and other people with advanced laboratory facilities, and took a year or more to achieve. Once produced in sufficient quantity, the handling and weaponizing of CW agents would be very hazardous. Another technological challenge lies in the need to stabilize CW chemically in order to increase their storage life.¹¹ If all these hurdles could be crossed successfully, however, then a small number of low-yield CW devices, perhaps intended for limited use by a terrorist group, would be relatively easy to hide and transport. A rather more straightforward option, of course, would be to buy or steal a supply of toxic industrial chemicals, for simple release in a crowded area.

Chemical Weapons: Delivery Systems

CW can be manufactured in solid, liquid or gas form. As such, the delivery of CW could be achieved in many ways; in vapour or droplet, delivered by truck or aircraft-mounted crop-sprayers, or by artillery shell, rocket or aircraft munitions. By 1991, for example, Iraq was developing several of these delivery systems, including aerial bombs, rocket warheads and missile warheads. Chemical agents can also be delivered in a more persistent 'dusty' form (such as 'dusty mustard' – see note 4), via a carrier particle such as talcum or diatomaceous earth. Another delivery option is aerosol; in June 1994, in the Japanese city of Matsumoto, Aum Shinrikyo conducted an attack using sarin in aerosol form, killing seven. For a limited CW attack, delivery could be achieved with much simpler means. Among many possibilities being discussed in the public domain – principally on websites – are crop-dusters, smoke generators and even air-conditioning systems. A conventional explosive attack could, for example, be given a CW effect simply by adding a chemical agent to the device, perhaps a home-made mortar or even something as small as a hand grenade. Aum Shinrikyo's attack on the Tokyo underground system on 20 March 1995 killed twelve and caused some 1,000 casualties, and was achieved with arguably the simplest means possible; sarin contained in a plastic bag, punctured with an umbrella and allowed to vaporize. Importantly, the Aum attack had a remarkably short-term effect on the functioning of the Tokyo subway, much like the July 2005 attacks on London's underground. Certain CW could also be used to poison food and water supplies, and could be introduced into buildings through air conditioning and ventilation systems. In general, CW are dependent for their effect on ambient weather conditions, and particularly on the temperature, the intensity of sunlight, the strength and direction of wind, and rain (especially, of course, for those agents soluble in water).

Chemical Weapons: Consequences of Attack

Other than the odours often associated with CW use (new-mown hay with phosgene, almonds with hydrogen cyanide), chemical agents could be deployed and released with little or no warning. The first indications would be victims displaying symptoms appropriate to the agent used. The 'human canary' effect would be most obvious with CW use, particularly where the release has been achieved stealthily (i.e. rather than explosively). The sudden and apparently inexplicable onset of symptoms of acute poisoning has by now become an important indicator of likely CW use. Personal recovery and site decontamination would be contingent upon the CW agent used. In some cases, provided the CW agent can be identified quickly enough, the effects of CW poisoning can be reversed using drugs.¹² Most non-persistent agents (such as, for example, sarin) can be cleaned up in hours by trained personnel using appropriate self-protection and decontamination equipment. However, persistent agents such as VX can take much longer to decontaminate and can create an extremely hazardous operating environment, particularly since some agents have been designed to be able to penetrate individual protective equipment. Depending upon the amount of agent used, and the dispersal mechanism, the contaminated area is likely to be reasonably well contained, although the movement of people and vehicles through and beyond the zone of contamination could help to spread the agent beyond the immediate area.

Chemical Weapons: Utility

CW agents have been used broadly in three ways: as a military weapon, on a military scale, against military targets; as a military weapon, on a military scale, against non-military targets; and as a terrorist weapon, on a small scale, against non-military targets. As far as the first of these is concerned, the history of CW use in war has been so vivid and shocking that the military potency of CW has, paradoxically, been undermined. Professional armed forces are so well trained and prepared to operate in a contaminated environment that the utility of CW on the battlefield against trained troops is open to question. That said, less well protected troops, in hospitals and logistics areas, would still be vulnerable to a CW attack. Moreover, since the performance of even the best-trained combat troops can be degraded by having to wear individual protection equipment for any length of time, the utility of CW might be said to reside in this marginal, harassing effect. The military-scale use of CW against open, civilian targets could have a devastating effect, as the Iraqis demonstrated in their attacks on Kurdish and Iranian populations in the 1980s. CW delivery on this scale, of course, would require a very significant military and industrial infrastructure, and responsibility for the attack would be difficult to deny. The final option – the terrorist use of CW against open, civilian targets – is arguably the most alarming prospect of all and seems likely to be of most interest to terrorist groups such as al-Qaeda. The scientific and technological infrastructure necessary to deliver such a limited or 'demonstration' CW attack would be complex but on a more manageable scale. The CW-armed terrorist group would be able to exploit the 'target-rich environment' of an open society with relative ease, and although the consequences of such an attack might be limited to no more than several hundred deaths and injuries, the inevitable publicity for the terrorist group and its cause could constitute a very compelling incentive.

There is some disagreement as to whether TIH or CW would be most suitable for terrorist use, if the latter which agent in particular, and which terrorist groups might be so inclined. Media reports claimed in 2004, for example, that an unidentified terrorist group planned an attack in Britain using an industrial chemical – osmium tetroxide¹³ – and that another group planned a CW attack in Spain in 2005 (using an unspecified CW agent).¹⁴ It is the availability and lethality of nerve agents that figure most prominently in media reporting and speculation, not least with

Aum Shinrikyo's activities in 1994–5 in mind. The activities and intentions of Osama bin Laden and al-Qaeda have been the focus of a great deal of media coverage of the terrorist CW danger, and not only since 9/11. It is widely accepted that al-Qaeda has for several years been committed to the acquisition and/or production of CW: a terrorist manual was found in Brussels in 1995, showing an interest in CW; in early 2001 Italian counterterrorist experts suspected an al-Qaeda interest in the acquisition and transport of CW; in July 2001 Ahmed Ressay testified in his trial that he had received training in the use of hydrogen cyanide at an al-Qaeda training camp in Afghanistan, including the exposure of dogs to AC; in November of the same year, US intelligence reports suggested that AC had been produced and tested in a village near Jalalabad, Afghanistan; and it is often reported that Osama bin Laden, in an interview with Pakistan's *Dawn* newspaper, declared that 'If America used chemical and nuclear weapons against us, then we may retort with chemical and nuclear weapons. We have the weapons as a deterrent.'¹⁵

Chemical Weapons: Sample Scenarios

According to one scenario/estimate, a military-style attack against an unprotected (i.e. non-military) population of a town or city (in order to achieve sufficient human density for effect), with a missile carrying a CW warhead containing 300 kg of sarin, would kill between 200 and 3,000, and injure a similar number. By comparison, the same missile carrying a 20 kiloton (kt) nuclear warhead would kill 40,000 and injure the same again.¹⁶ This estimate appears to be broadly consistent with another, made in 1999 by the US Department of Defense. The Pentagon estimated that in an urban area the open-air dispersal of about 22 lb of sarin (c.10 kg) would kill about 50 people, that 220 lb (100 kg) would kill 500, and that 2,200 lb (1 tonne) would kill tens of thousands.¹⁷ An attack using sarin would be among the most sophisticated scenarios imaginable. At the other end of the scale, an attack with a more commonplace toxic chemical which killed no more than, say, one hundred would still be regarded as a very significant terrorist attack.

Chemical Weapons and Terrorism: Assessment

Chemical weapons have a long history of research, development and production for use on the battlefield. But in the environment of the battlefield, the effect and therefore utility of CW have to a considerable extent been neutered through training and preparation, and through the provision of protection and decontamination equipment, and antidotes. It is largely for this reason that many military experts, or analysts familiar with the military perspective, find it difficult to describe CW as a 'weapon of mass destruction'. Against a well-trained and properly equipped military force, the use of even the most potent CW agent might be seen as not much more than an irritant, and a passing one at that.

But complacency of this sort would, of course, be entirely inappropriate where CW are used in a non-military environment; against an unprotected civilian population, for example, which would be the most likely target for terrorists. In such an environment, the public (and therefore the democratic political elite which responds to public concerns) would be unlikely to sense much more than the narrowest of margins for optimism, escape or recovery. The lethality of CW (particularly nerve agents such as sarin) is widely perceived to be so extreme, the availability of CW (or TIH) so widespread, and the vulnerability of any single, unprotected person so complete, that the working assumption in the public/political mind is that the use of chemical agents against an open target is both possible and certain to lead to near-instant death for its victims. In addition, the fact that sudden death could come from colourless and (in some cases) odourless liquids and gases released covertly adds to the fear of an unknown and unknowable

danger. In other words, whatever the battlefield utility of CW, and whatever the qualities of the different agents, as far as public opinion is concerned CW are a terrorist weapon *par excellence* – an observation that is not likely to have been lost on terrorist groups.

To produce CW in large-scale quantities is challenging scientifically and technologically, and the handling and weaponizing of CW are generally understood to be very hazardous. For terrorist groups seeking a weapon of extreme mass effect, against unprotected populations in towns and cities, either biological or nuclear weapons (discussed below) might therefore be of more interest than CW. But for a very committed and well-funded terrorist group the difficulties associated with CW might not be thought insurmountable. However, terrorist groups vary enormously in size, sophistication and capability, and in the effect being sought. It could be that a small terrorist group – or even one part of a much larger organization – might have as its objective a Tokyo-scale attack on public transport, for which CW (or TIH) could be the ideal means, delivered simply. The knowledge that such an attack could trigger an immediate and disproportionately terrified response on the part of the structurally vulnerable target population could persuade some terrorist groups in the future to take the CW path.

3 BIOLOGICAL WEAPONS

Biological Weapons: Characteristics

Vulnerability to disease is a fact of life, and a fact that has been exploited throughout history; the deliberate, targeted conveyance of disease is not a novel proposition. Commentators frequently draw upon examples of rudimentary biological warfare from Persian, Greek and Roman literature. In medieval warfare, plague victims and rotting animal carcasses were catapulted over the walls of besieged castles and fortifications, or used to poison sources of drinking water. In the eighteenth century, smallpox-infected blankets were distributed by the British to native tribes in North America, and similar methods were used by Brazilian landowners against South American native tribes in the twentieth century.¹⁸ What is a more modern phenomenon, however, is the isolation, culturing, mass production and weaponizing of pathogens – lethal bacteria, viruses and other micro-organisms – and antigens and toxins.

Biological warfare agents can be classified in a number of ways. One distinction to be drawn is between micro-organisms and toxins. Micro-organisms (e.g., bacteria, viruses, rickettsiae and fungi) depend for their effect on survival and/or multiplication within a target body and can include contagious BW (i.e. smallpox,¹⁹ plague,²⁰ Ebola²¹ and dengue fever²²) and non-contagious BW (i.e. anthrax²³ and tularaemia²⁴). Biological toxins are poisonous products of organisms, are inanimate and cannot reproduce themselves, and are intended to have effects broadly similar to CW. Biological toxins include substances such as saxitoxin,²⁵ botulinum toxin²⁶ and ricin.²⁷ Another, arguably more sophisticated classification system divides BW into Categories A, B and C according to disease type:

- *Category A.* Including organisms that cause anthrax, botulism, plague, smallpox, tularaemia, and some 18 viral haemorrhagic fevers (VHFs, including Ebola and Marburg). Category A agents have the greatest potential for large-scale casualties, and therefore offer the greatest challenge to public health management and recovery, and to the management of public risk perceptions.
- *Category B.* Including Q fever (a febrile disease caused by zoonotic rickettsiae), brucellosis, encephalitis, typhus and toxic syndromes. Category B would also include common food-borne agents such as salmonella, clostridium perfringens and escherichia coli. Category B agents have a more moderate effect on public health and are more manageable than Category A agents.
- *Category C.* 'Emerging threat agents' that are not currently considered to represent a high bioterrorism risk, but which could develop as such in future. Category C agents include Nipah virus and various encephalomyelitis viruses.²⁸

The Biological Weapons Convention (BWC)²⁹ was opened for signature in 1972 and entered into force in 1975. 152 countries have ratified or otherwise acceded to the BWC, with a further 16 signatories yet to proceed to ratification. The prohibitions within the BWC apply both to pathogenic micro-organisms (bacterial, viral and other), and to biological antigens and toxins, whether naturally or artificially created. The BWC prohibition on toxins was instrumental in the development of the Chemical Weapons Convention. Although the BWC has been in force for several decades, and although the Convention has considerable formal support internationally, it is widely accepted that the BWC is still too weak institutionally, that its implementation provisions fall far short of expectations, and that it is severely disabled by the absence of an effective verification system.

Biological Weapons: Availability

By one argument, biological weapons 'combine maximum destructiveness and easy availability'.³⁰ A BW programme could draw upon a good deal of dual-use equipment and technology,³¹ it might make use of the BW 'recipe books' which are reportedly available on the internet and elsewhere (for ricin, botulin, potato and nicotine poisons for example), and might require only a small research, development and production programme which would leave little or no signature and therefore be easy to conceal. It is important, however, not to exaggerate the availability of BW. BW production involves four stages – acquisition, production, weaponization and delivery – the first three of which are progressively more difficult:

1. *Acquisition.* It would not be easy to acquire the seed stock of a pathogen or a toxin-producing organism, but it would not be impossible either. One option would be theft, from one of the 1,500 germ banks dotted around the world, or from a research laboratory, hospital or public health laboratory.³² Not all of these facilities can be expected to maintain the highest possible levels of physical and human security. It is conceivable that a scientist or technician with legitimate access to key materials and organisms might be suborned by or volunteer to assist a terrorist group, or even set out as a one-man band to avenge some terrible grievance. Another option would be fraud. In one celebrated example, in 1995 an American white supremacist, Larry Wayne Harris, applied to the American Type Culture Collection for the bubonic plague bacterium. Harris's application was, fortunately, found to be fraudulent and he was prosecuted and imprisoned. For the most sophisticated BW proliferator, gene synthesis might offer another option: 'Armed with a fake e-mail address, a would-be terrorist could probably order the building blocks of a deadly biological weapon online, and receive them by post within weeks. [...] Dozens of biotech firms now offer to synthesise complete genes from the chemical components of DNA.' Often, the companies concerned are lax in their security screening of requests for DNA sequences, with the result that 'terrorists could order genes that confer virulence to dangerous pathogens such as the Ebola virus, and engineer them into another virus or bacterium.'³³ The prospect of genetic modification (GM) of BW has begun to capture the imagination in recent years:

*GM bacteria, viruses or prions could be more infective; resistant to antibiotics and vaccines; targeted at specific organs; able to lie dormant without detection before causing disease (stealth organisms); and have greater environmental stability and survivability. GM anthrax, a modified smallpox immune response that would render current smallpox vaccines ineffective, and a synthetic poliomyelitis virus are prime candidates.*³⁴

2. *Production.* The manufacturing of BW agents is not straightforward. Bulk production, in particular, would be demanding and dangerous.

3. *Weaponization.* Weaponizing a BW agent is yet more challenging, for two reasons. First, the health and safety of those involved in BW production could scarcely be more at risk. Quite apart from the hazard of handling highly dangerous micro-organisms and toxins, in a covert production process the personal protection of laboratory workers and the reliability of laboratory equipment are unlikely to be considered a priority. It might prove difficult to persuade scientists and laboratory workers to agree to work under such conditions. Second, it would not be a simple matter to produce a stable device with a predictable effect. BW agents are, in general, vulnerable to environmental and weather

conditions. Some BW agents present specific challenges; anthrax spores, for example, are known to 'clump' too easily when inadequately aerosolized. It must be borne in mind, however, that for a terrorist group seeking a 'single-shot' BW attack, safety, reliability and predictability in both production and weaponization might not be of great concern.

4. *Delivery.* Once the first three stages have been passed through successfully, the delivery of a BW device would be a relatively simple matter. There would be more than enough targets on offer, and more than enough delivery means available (see below) to ensure a more or less successful attack.

The experience of Aum Shinrikyo illustrates well the case for a measured assessment of the availability of BW. Accounts indicate that the group tried to acquire or produce *Clostridium botulinum* (the organism producing botulin), *Bacillus anthracis* (anthrax) and *Coxiella burnetii* (the bacillus causing Q fever³⁵). The group tried to acquire laboratory equipment and growth medium (peptone), and tested dispersal of BW agents by aerosol. However, all these efforts, by a very dedicated and well-funded group, came to nothing. Judging by this case alone, it seems reasonable to suggest that the production of BW is not, after all, a simple matter. But there is a cautionary point to note: by one account Aum Shinrikyo's failure should be attributed to the group's own shortcomings, but not to the success of the various material control and non-proliferation arrangements supposedly governing access to BW.³⁶ The question remains, therefore, whether another organization could achieve the technical success which eluded Aum Shinrikyo, particularly one such as al-Qaeda which takes a rather longer view of the conflict to which it is committed and which might allow more time to develop technologies and weapons.

Biological Weapons: Delivery Systems

There are many possibilities for the delivery of BW, and in the 1990s it seems that Iraq experimented with most of them: missile warheads, aerial bombs, aircraft spray systems, pilotless aircraft, aerosol generators (including those mounted on pilotless aircraft), landmines, cluster bombs, rocket warheads, and artillery shells (perhaps even for the Supergun project).³⁷ Other options which feature in discussion about the dangers of BW use include truck-mounted spray systems, crop-dusting aircraft, contamination of water and food supplies, the use of individuals infected with a highly contagious disease as a carrier, and the dispersal of infected insects. The number and variety of possible delivery systems does not, however, necessarily indicate the level and extent of the BW danger. The delivery of airborne viral BW, for example, would require very advanced biotechnical skills, and would pose a very high risk to technicians and operators.³⁸ More generally, it should always be borne in mind that BW use would inevitably be a complex undertaking, drawing upon many branches of science and technology, including microbiology, pathology, aerosol physics, aerobiology and meteorology.³⁹

Biological Weapons: Consequences of Attack

The first problem with assessing the possible or likely consequences of a BW attack is that it might be very difficult to be sure where and when a BW attack has taken place. BW agents can be introduced in many ways, several of them undetectable, such that it might be impossible to know that an attack of any sort has occurred. Except in the unlikely case of massive doses of the most aggressive toxins being delivered in an attack, BW could not have an immediate effect since they must incubate in the body before they can act; with some BW agents, it might take days or weeks for symptoms to materialize. The delayed recognition of a BW attack creates great difficulties for the management of the consequences of an attack. Particularly where a contagious disease is involved, the delay could mean that infected victims, unaware of their

predicament, might spread the disease far and wide. In this scenario, with a dispersed and dispersing population and an ever diminishing chance to ascertain who is infected and who is not, the medical management of the consequences of the attack would be problematic. Even if these difficulties could be overcome promptly, differences in the strength, persistence and medical effects of the various BW agents would represent an enormous challenge to medical and emergency services. The physical health and immunity (both individual and herd) of the victims of a BW attack would also influence the outcome of the attack. But by the same token, the relative lack of clarity and certainty of effect surrounding a BW attack begs the question whether a terrorist group would be sufficiently interested in BW as a means of attack.

Biological Weapons: Utility

BW would be much easier to acquire or manufacture than nuclear weapons, and could have a bigger impact on public and political consciousness than chemical weapons. For these general reasons, some analysts would argue that BW are becoming the terrorist's 'weapon of choice'. Closer investigation suggests a different interpretation, however. The procurement, handling, weaponizing and uncertainty of effect of BW make these weapons very difficult choices for terrorists, not least with the need for self-immunization before work can begin. With some notable exceptions, BW are generally slow-acting. Some micro-organisms can be very sensitive to climatic conditions and can decompose rapidly, and some viral agents can be damaged even by exposure to sunlight.⁴⁰ For all these reasons, BW were not considered to have much conventional battlefield use, and might be of limited value to terrorists.

But terrorist interest in biological weapons should not be down-played. According to the March 2005 *Report to the President of the United States by the Commission on the Intelligence Capabilities of the United States Regarding Weapons of Mass Destruction*, from the late 1990s al-Qaeda members had trained in producing biological agents such as botulinum toxin and toxins from venomous animals, as well as developing a particularly dangerous strain of a biological agent known for security reasons only as 'Agent X'. The US intelligence community judged that al-Qaeda had 'probably' acquired a small amount of Agent X and had plans to produce dispersal devices. After the collapse of the Taliban in 2002, evidence was uncovered to indicate that al-Qaeda's BW programme 'was extensive, well-organized, and operated for two years before September 11 [2001].'⁴¹ Similarly in the United Kingdom, the July 2004 *Review of Intelligence on Weapons of Mass Destruction* (usually known as the 'Butler Report' after the committee chairman Lord Butler) reported that in 1999 Osama bin Laden had planned to attack British and American targets in India, Indonesia and the United States, and referred to the discovery in post-war Afghanistan of a BW laboratory in Kandahar and to evidence that appropriate scientists had been recruited.⁴²

Western societies' visceral sense of vulnerability to BW, and to disease in general, provides another reason to suggest that it would be imprudent to dismiss BW too readily. This pervasive feeling of defencelessness means that BW have almost become a weapon which the victim inflicts upon himself. Psychological vulnerability of this sort could be exploited by terrorists with relative ease (i.e. with a very small, low-yield device, or perhaps even with a series of one or two hoaxes). The 2001 anthrax hoaxes in the United States (over 600) must at some point have become self-limiting in their effect, but this was a sequence of events which gripped the United States and which captured political attention around the world, certainly because of its proximity to the 9/11 attacks and because the Washington sniper murders happened at about the same time. Although the anthrax hoaxes were probably not the work of terrorists, this might be something from which terrorists could learn. In the terrorist's mind, even the language or threat of a BW attack could offer a high level of celebrity and media/public

interest, even to the point of arguing that 'A terrorist is more likely to threaten to use a biological agent rather than actually use it.'⁴³ Then again, if the 'BW threat' exists largely in the Western mind, it ought to be possible to find countermeasures in the same place.

Biological Weapons: Sample Scenarios

Biological warfare scenarios vary somewhat in their casualty estimates. A 1970 study by the World Health Organization suggested that 50 kg of anthrax spores released from an aircraft flying over a city of 5 million people could cause 250,000 casualties, of whom 100,000 would die if not treated. Yet in 1993 the US Congressional Office of Technology Assessment estimated that 100 kg of anthrax released by aerosol upwind of Washington, DC could cause 13,000 deaths.⁴⁴ In a more recent scenario, a single missile carrying 30 kg of anthrax spores launched against a largely unprotected target is assessed to cause between 20,000 and 80,000 deaths.⁴⁵ Another estimate suggests that 50 kg of anthrax released by an aircraft flying along a 2 km path upwind of a city of 500,000 could cause 125,000 casualties with 95,000 deaths. In the same study, 50 kg of the Q Fever bacillus *Coxiella burnetii* is expected to cause 125,000 casualties with only 150 deaths.⁴⁶ Anthrax usually figures prominently in BW scenarios, but it must be said that the very limited practical experience of the effects of exposure to anthrax would support a more cautious assessment of casualties and fatalities. In 1979 an accident at a Russian military site led to some 65,000 people being exposed to anthrax spores. Of these, only 70 were reported to have been infected with anthrax, of whom 68 died.⁴⁷ The anthrax attacks in the United States in late 2001 also had a very limited medical effect, albeit with widespread social and political impact. On balance, however, the conclusion to be drawn from these scenarios, in which in most cases the effect would dwarf any previous terrorist attack, is that if the difficulties associated with BW production and use could be overcome, then a large-scale BW effort could easily appeal to a very committed terrorist group with a long view.

Biological Weapons and Terrorism: Assessment

There are several reasons to suggest that too much has been made of the prospect of bioterror. The effect of BW seems to be an open question; BW are widely acknowledged to be of marginal utility on the battlefield, and scenarios in which BW are used against an unprotected civilian population vary widely in their casualty estimates. An all-out, systematic bioterror attack could, furthermore, scarcely be seen as a commonplace possibility; the acquisition, production, weaponization and delivery of BW are all sufficiently difficult and dangerous to maintain a high threshold to BW use, at least for the present. Yet in spite of these cautionary words, there can be little doubt that the impact of terrorist use of BW could be profound, and there might prove to be more than enough BW-related terror available below the threshold. Bioterror – even at a low level and even in a bungled attack, and even if only threatened – would certainly make a deep and lasting impression on public psychology: 'To the extent that terrorists are interested primarily in producing panic and fear instead of mass death, biological weapons have also been described as the ultimate terrorist weapon, because the use of biological weapons by terrorists would produce a great deal of panic and fear, while killing very few people. This is because of the difficulties involved in weaponizing a biological agent.'⁴⁸ But some analysts take a much more pessimistic line, arguing that the BW threshold is not at all high, and that even the weaponization hurdle is surmountable: 'It is clear that biological weapons present the greatest danger today ... as they are the easiest to acquire, have the weakest regimes and yet have effects comparable to nuclear weapons.'⁴⁹ Taking the latter view, BW could offer the worst of all possible prospects, in that they are both available and usable, and could cause both mass terror and mass casualties. This possibility need be only in the slightest part plausible for it to generate public concern and to command the attention of political elites.

If public opinion and political action are to be nudged in a precautionary direction where BW are concerned, the difficulty is in what should then be done. The international BW problem is driven both by 'supply push' and 'demand pull'. Commercial research and development are proceeding apace (in pesticides and anti-virals, for example); there could well be too many unscrupulous micro-biologists and research scientists willing to work for the highest bidder; and an increasing amount of BW-related technology and equipment is dual-use, i.e. readily available in commercial and civil applications. The principal framework for the regulation of this ever-increasing activity is, however, the inadequate Biological Weapons Convention. On the demand side, there is some evidence that terrorist groups intend to acquire BW. This intention could be either attributable to or amplified by years of open speculation in Western societies about the vulnerability to BW attack; weaknesses have been advertised freely, and it is reasonable to suppose that an adversary might seek to exploit them. But even if the evidence has been exaggerated, and even if the BW danger resides only in the neurotic imagination of Western publics and political elites, the possibility of BW-equipped malign intent cannot be discounted altogether and must therefore be acted upon.

Yet if the supply and demand dynamics are as described, then the breadth and pace of the BW problem could be beyond the scope of governments and international bodies. The global BW-related research and development cycle could simply be moving too fast for governments to keep pace. Governments and international health bodies might work to develop countermeasures and health management plans for terrorist attacks using, say, anthrax or Ebola. These mass vaccination and disease control plans could take several more years to develop and establish. And during that time, the global BW network/laboratory might well have come across wholly new ideas and techniques which could be developed and deployed by terrorist groups while their target governments are still putting the finishing touches to the previous generation of countermeasures. This presents the greatest possible challenge for governments, health bodies and security forces: to prepare for and deal with both the current BW danger, which to the extent that it is known must inevitably be understood and described as massive, as well as the prospective BW danger, which is largely unknown.⁵⁰ In other words, while understandably distracted by the possibility of an imminent, large-scale anthrax attack, governments must also draw upon the patchiest of information to construct countermeasures that will be relevant and effective ten or more years in the future, against agents and techniques which at present reside largely in the imagination. All this suggests that where BW are concerned, the traditional intelligence-driven, threat-based approach, where a premium is placed on assessments of malign intent and of capabilities, might not be all that useful. The following quotation offers a succinct summary of the problem:

Even if we had perfect intelligence information about the current state of the bioterror threat – if we knew the intentions of every person seeking to do harm with biological agents, and we knew exactly what they were capable of – we would not necessarily know how to structure a biodefense program that may take years to develop countermeasures. [...] the rapidly increasing capability, market penetration, and geographic dissemination of relevant biotechnical disciplines will inevitably bring weapons capabilities within the reach of those who may wish to use them to do harm. If it takes close to a decade to develop and license a new therapeutic vaccine, it is not today's threat but the threat a decade from now that we need to counter. And given how much easier it is to pose a threat than to counter one, the threat ten years out may not even materialize until eight or nine years out.⁵¹

4 RADIOLOGICAL WEAPONS

Radiological Weapons: Characteristics

The purpose of a radiological weapon (RW; otherwise known as a radiological dispersion device or RDD) is to spread radioactive material over a wide area using either an explosive device (usually described as a 'dirty bomb') or some other means of dispersal. Radioactive material of various types can be acquired from a wide variety of sources (see below). The ready availability of such material, and the supposed ease with which it could be distributed, have led to a widespread sense of vulnerability to RW attack and even, in some quarters, to the belief that the RW would be the terrorist's preferred weapon. But while RW are acknowledged to have seized the public imagination, and while the use of such devices could have serious economic consequences, these consequences would be limited.⁵²

The simplest method by which to deploy radiological materials to lethal effect would be to release a highly toxic radioisotope as a local poison, as was demonstrated by the use of polonium-210 in the November 2006 presumed murder of Alexander Litvinenko in London. The smallest type of explosive RW would involve a mass of high explosive (perhaps less than 100 kg) jacketing a relatively small radioactive source of between 1 and 10 Curies.⁵³ A radiological attack on this scale would not cause mass casualties, but would certainly cause disruption, panic and economic damage. At the other end of the scale, however, the 'maximum credible event' could be a device (explosive or other) designed to distribute tens or even hundreds of thousands of Curies of radioactive material. Little work has been done to model the effect of such an attack, but Zimmerman and Loeb offer this pessimistic judgment: 'Some of the major international terror groups, including al-Qaeda, have not only the resources to carry out such an attack, but also the willing martyrs, whose participation would significantly reduce the cost and complexity of any protective systems needed to allow the perpetrator to survive long enough to carry out the attack.'⁵⁴ Analysts, however, remain divided as to the number of deaths and immediate injuries resulting from a RW attack.

Radiological Weapons: Availability

Radiological materials are used in a wide variety of circumstances: general industry, agriculture, medicine, communications and navigation. But not all radioactive isotopes would be suitable for RW use. Among the candidates, 'only a few stand out as being highly suitable for radiological terror': cobalt-60; strontium-90; yttrium-90; caesium-137, iridium-192, radium-226, plutonium-238, americium-241 and californium-252.⁵⁵ The storage, sale and shipment of these materials are not as controlled as they could be, with safeguards far less rigorous than those applied to reactor- or weapons-grade uranium and plutonium. According to one analyst: 'Radiological materials that can be used in [a radiological dispersal device] exist in a variety of forms in virtually every country of the world, and are generally loosely monitored and secured.'⁵⁶ The US Nuclear Regulatory Commission has estimated that one licensed US radioactive source is lost every day.⁵⁷ The problem is compounded, of course, when it is realized that from the perspective of the general public, *any* radioactive material is highly toxic, and there would thus be a general disinclination calmly to suspend judgement regarding a RW attack until it could be established whether the isotope was one of the most dangerous, on the list just quoted.

Terrorist acquisition of reactor- or weapons-grade highly enriched uranium-235 (HEU) or separated plutonium (Pu-239) would seem to represent the gravest danger of all in the

spectrum of RW possibilities. According to a 2005 Carnegie Endowment report, there is a global stockpile of some 1,855 metric tons of plutonium in the world (1,700 tons in civil stocks and 155 tons in military), together with some 1,900 tons of HEU (175 tons civil and 1,725 tons military) – enough fissile material for about 100,000 nuclear weapons.⁵⁸ Of particular concern are the 135 civil research and test reactors around the world, in a variety of situations and under varying levels of security. The vast majority of these reactors are estimated to stock a minimum of 20 kg of HEU.⁵⁹ Nevertheless, some analysts argue that HEU is not suited to RW use (in part because the lethality to any handler would require massive and cumbersome shielding), and that in any case, HEU and Pu-239 are generally much better secured than lower-grade nuclear waste, and therefore less attractive for the RW-intent terrorist. Spent fuel rods (from both power and research reactors) might make extremely good RW contaminants but, once again, this material is better safeguarded than lower-grade radioactive material and would therefore be more difficult to acquire.

Radiological Weapons: Delivery Systems

The optimal delivery system for a radiological weapon is generally assumed to be a high explosive device which distributes the radioactive isotope(s) randomly by blast. However, as Zimmerman and Loeb point out, radioactive material can be distributed in a variety of ways; some isotopes can be dissolved in a solvent and poured or sprayed, others can be burned or vaporized.⁶⁰ From the point of view of a terrorist group, non-explosive delivery might offer an advantage in that authorities might be slow to suspect and detect radiological release. In the delay, radioactive material might be ingested or inhaled by yet more people, and radioactive pollution allowed to spread still further.

For larger RW devices, the radioactive mass at the heart of the device could be of such a size and lethality that extensive shielding would be required to allow the device to be assembled. But the device might then be so large and heavy that it could scarcely be moved, at least not without attracting unwelcome attention. However, as Zimmerman and Loeb have suggested, a terrorist intent on martyrdom might be willing to handle large quantities of lethal radioactive isotopes with no concern as to safety and protective measures.

Radiological Weapons: Consequences of Attack

The use (or threatened use) of a radiological weapon would have a number of consequences: physical, political and economic. If the dispersal of radioactive material has been achieved through the use of high explosives (i.e. in a 'dirty bomb'), then one category of *physical* harm will be the traumatic injuries caused by the initial blast and associated flying objects (perhaps contaminated). Some analysts argue that the injuries and destruction caused by the initial explosion would exceed the radioactive damage. Put another way, those victims close enough to the centre of the RW event to receive a serious radiation dose would be more likely to be killed promptly by the bomb blast than through rapid onset of radiation sickness.⁶¹ But radiation can, of course, be extremely harmful, particularly if alpha or beta particles are inhaled or ingested in, say, the dusty environment just after the blast. Symptoms of radiation sickness can include topical burns, vomiting, major blood disorders, gastrointestinal damage and, in extreme cases, death. In the longer term, some victims might develop cancers. An explosive radiological release could also cause a plume of contaminated material to rise which, subject to climatic conditions, could create a radioactive downwind hazard.

Political harm would come in the form of public panic about radioactive pollution and poisoning, and in the form of rumour and conspiracy theories concerning any clean-up and decontamination operations, and mistrust of government assurances that decontamination had been completed successfully. Even the threat of RW use can have a political impact. A radiological device containing caesium-137 was planted by Chechen terrorists in Izmilovsky Park, Moscow in November 1995. Although the device was not detonated, and by some accounts would not have caused great damage, the threatened attack was important symbolically for the Chechens and psychologically for the people of Moscow. Finally, the *economic* harm associated with use of a radiological weapon would be a simple consequence of having to shut down office and residential areas, factories, facilities and communications infrastructure while decontamination was carried out, perhaps for several weeks or months (or even, in the event of severe contamination on the Chernobyl scale, forever).⁶² Small businesses, particularly those relying on daily trade, would collapse, local unemployment would rise, tourism would cease. The export of manufactured goods from contaminated factories and areas would be suspended, for fear of spreading contamination. Depending on the quality of business recovery and substitution plans, the effect of large-scale evacuation and closure on the world's major financial centres could be extreme.

Radiological Weapons: Utility

The assembly and handling of a radiological weapon would pose some challenges to a terrorist group, and very severe hazards. However, for groups and individuals willing to endure these physical risks, the challenges would not be insurmountable. A recent report by the US Federal Emergency Management Agency has noted that '[radiological weapons] require very little technical knowledge to build and deploy compared to that of a nuclear device.'⁶³

We have seen that there would be several physical effects of RW use; the initial high explosive blast, followed by immediate and then longer-term radioactive contamination. Although most analysts accept that the number of deaths and injuries would be insufficient to justify the label 'weapon of mass destruction', the immediate blast and contamination effects would create panic among a less knowledgeable and discerning public, making RW at least a 'weapon of mass effect'. The likely (or imagined) longer-term medical consequences – cancers and other illnesses – would add to this effect, even though a causal connection between the disease and the RW event would be medically and statistically difficult, if not impossible, to establish. Both the physical and the political effects could be precisely what the terrorist seeks; the publicity surrounding such an event and its consequences would be massive and enduring, and public reluctance to believe assurances regarding decontamination could undermine the legitimacy and authority of government. The economic disruption caused by a RW attack would, similarly, be welcomed by the terrorists responsible.

Radiological Weapons: Sample Scenarios

Scenarios for RW use and effect are among the most speculative; there have been contamination events which provide a useful analogue for gauging the effect of a small radiological device, but there has been relatively little modelling of the effects of a large-scale RW attack on a city. There appears to be a reasonably firm consensus in the literature that while the political and economic effects of a RW attack could be extreme, only the largest conceivable RW device could kill more than scores or hundreds of people.⁶⁴ Thus, a recent US Department of Defense study estimated that a 100 lb (45 kg) RW device carried in a backpack, containing radioactive material used for cancer treatment, detonated in a city centre, would kill no one through radiation. However, a truck-borne device using a similar amount of explosive

but with about 100 lb (45 kg) of spent nuclear fuel rods could cause lethal doses of radiation within a half-mile radius.⁶⁵

Radiological Weapons and Terrorism: Assessment

The physical harm from a RW attack would be limited, but the political and economic damage could be severe. As a fairly novel national security scenario, it is difficult to assess how any government might respond to the enormity of large-scale, explosive RW use, other than to focus on immediate decontamination and public health, and on rebuilding economic confidence. Planning ahead, more could and should be done to restrict access to radiological material, particularly so-called 'orphan sources' – poorly controlled radioactive sources with industrial or therapeutic applications. Decontamination systems could also be improved, and the public tendency to panic could be diminished through public education and reassurance as to the actual hazards involved. Similarly, the economic consequences of RW use could be moderated through careful business continuity planning. All these measures and preparations might have a passive deterrent effect on the terrorist, who might perceive the likely effects of a RW attack to be increasingly contained. Yet there is little by way of active or punitive deterrence on offer, focusing specifically on groups contemplating RW use. Simple cost-benefit analysis suggests that for terrorist groups and individuals – particularly those for whom personal safety when handling radioactive material is not a priority – the acquisition and use of a radiological weapon will remain a tempting prospect.

5 NUCLEAR WEAPONS

Nuclear Weapons: Characteristics

Although various nuclear isotopes are used in the construction of a nuclear weapon, at the core of any device must be a mass of sub-critical fissile material – either highly enriched uranium-235 (HEU) or separated, ‘weapons-grade’⁶⁶ plutonium (Pu-239). Depending upon the sophistication of the device, estimates vary as to the amount of either HEU or Pu-239 needed to make a nuclear weapon. The IAEA defines the ‘significant quantity’ (i.e. the quantity necessary to construct a nuclear device) of HEU and Pu-239 as 25 kg and 8 kg respectively. Some analysts argue, however, that as little as one-tenth of these quantities would be sufficient.⁶⁷ In theory, uranium enriched to as little as 20 per cent U-235 could be used in an explosive device – although, as Bleek points out, several hundred kilogrammes of such low-grade uranium would be required.⁶⁸ Whatever the purity of the fissile material, the central challenge to nuclear weapon designers and manufacturers is to find a way to ensure that the fissile material is brought very rapidly to a supercritical state in order for the resulting reaction and detonation to be fully efficient.⁶⁹ The alternative, whereby the supercritical state is reached too slowly or by too little of the fissile material, would see an inefficient reaction and detonation, with fissile material being blown apart rather than fuelling an efficient chain reaction. This is known endearingly as a ‘fizzle’.

The initiation of a nuclear device is achieved by detonation of high-quality, ‘superfast’ explosive, in one of two ways. The simplest of these is the ‘gun device’ – the type of device used over Hiroshima in 1945, and latterly developed clandestinely and indigenously by South Africa. The gun-type device requires two sub-critical masses of HEU (Pu-239 will not work in such a device) to be shot very rapidly into each other to create a supercritical mass and initiate a chain reaction. The science involved is robust, reflected in the fact that the device used over Hiroshima was an untested prototype. The more complex (and far more efficient) alternative is an ‘implosion device’, whereby a smaller, spherical quantity of sub-critical fissile material (either Pu-239 or HEU) is compressed very rapidly by the precise detonation of a surrounding mass of high explosive. Upon compression, the fissile material reaches a supercritical state and the chain reaction begins. Perfectly simultaneous and symmetrical detonation of the entire high-explosive jacket is achieved using lenses and reflectors, and sophisticated high-speed switches known as krytrons. The implosion technique is also used to initiate the more sophisticated thermonuclear weapon, which uses the energy of the fissile chain reaction to initiate a fusion reaction, creating yet more fissile material and thereby increasing exponentially the energy yield of the device. In all cases, very high levels of energy are released in various forms.⁷⁰

Neither Pu-239 nor U-235 is available naturally, but both can be manufactured from naturally occurring uranium-238. Uranium ore must first be mined and then dissolved in sulphuric acid, before being ‘recovered’ in a solid form as uranium oxide (otherwise known as ‘yellowcake’). Uranium oxide must then be ‘converted’ into the gas uranium hexafluoride, where the proportion of U-235 is about 0.7 per cent. The next step in the process is ‘enrichment’; a complex engineering process necessary even for the production of reactor-grade low-enriched uranium (LEU), which requires between 3.5 and 5 per cent U-235. Weapons-grade HEU requires at least 93 per cent U-235 and thus the enrichment process is far more complex. Various enrichment methods are available: gaseous diffusion; centrifuge, electromagnetic or laser isotope separation. Pu-239 is an inevitable by-product of the irradiation of U-235 in any U-235 reactor (even an LEU-fuelled power reactor).⁷¹ Pu-239 must be ‘separated’ by complex chemical processes before it can be usable in a weapon.

Nuclear Weapons: Availability

High standards of engineering design and manufacture are necessary for successful manufacture of a nuclear weapon. These standards are, however, becoming steadily more attainable, particularly among developed and industrialized economies. There are several stages in the development of a nuclear weapon, each of which offers particular challenges in science and engineering:

1. The weapon design phase (or the acquisition of a design);
2. Production of fissile material for the sub-critical weapon core (or the acquisition of such material externally);
3. Fabrication or acquisition of non-nuclear parts of the device, including high-explosive elements, triggers and detonators;
4. Assembly into a deliverable nuclear weapon/device.⁷²

Several of these development stages would present very difficult challenges to a small non-state actor, such as a terrorist group. But these challenges are, once again, not insurmountable, particularly where the organization is well funded and where a simpler, gun-type device is intended. There must also, of course, be a conviction on the part of the terrorist group that acquisition of a nuclear device would be in its interests, or in the interest of the cause to which it is dedicated. This is an important threshold, since it is widely accepted that in the past, most terrorist groups and campaigns have acknowledged and accepted a taboo against acquiring, threatening and using a nuclear weapon.

As far as the design phase is concerned, technical literature on nuclear weapon design can be found in various sources (although claims that useable blueprints of gun-type atomic bomb design can be found in *Encyclopaedia Britannica* or on the internet are apocryphal). In the 1960s, graduate students were reportedly invited to develop a nuclear weapon design using only open sources, and apparently achieved the goal.⁷³ Graham Allison, writing in late 2003, claimed that 'given the right materials – a grapefruit- or soccer ball-sized amount of fissionable material is sufficient – several masters-level engineering students ... with several hundred thousand dollars and the type of equipment you could purchase off the shelf at Radio Shack could make a device that would explode. The last time I checked, researchers at Los Alamos, trying to develop strategies to combat this threat, had come up with sixty-nine different workable designs for a nuclear device.'⁷⁴ Barnaby makes a similar point: 'The difficulty of designing and fabricating a nuclear weapon ... is often exaggerated. A competent group of nuclear physicists, and electronics and explosives engineers, given adequate resources and access to the literature, would have little difficulty in designing and constructing such a weapon from scratch. They would not need access to any classified literature.'⁷⁵

Various key materials, components and technologies, such as rare nuclear isotopes, electronic components such as krytrons, and machines able to mill fissile material into spherical forms, are all highly specialized and difficult to acquire. But some key electrical components have been traded illegally, and even guidance systems could be available through black market trading. Bulk fissile material – the core of any nuclear explosive device – is also difficult to acquire, but possibly not difficult enough. Historically, world stocks of Pu-239 and HEU have not been adequately monitored and safeguarded, and it is conceivable that small quantities of either could be traded illegally. The Soviet nuclear arsenal was estimated, in late 1991, to include the following: 9,357 strategic warheads; 15,000–30,000 tactical warheads; a stockpile of HEU in excess of 1,000 tonnes; and a stockpile of Pu-239 in excess of 100 tonnes. Accounting

procedures were rudimentary. The then Minister of Atomic Energy Victor Mikhailov is reported to have observed: 'Nobody knows the exact capacities for the production of these [fissile] materials [or] the exact quantity of the produced materials themselves due to technological losses in production.' Fear of 'nuclear leakage' through sale, theft and diversion ran high in the early 1990s,⁷⁶ and continues to do so.⁷⁷ More recent assessments suggest that some 650 tonnes of weapons-grade fissile material (HEU or Pu-239) are in storage in the former Soviet Union, but that less than 50 per cent of this material has been subject to security upgrades to limit the possibility of theft or other 'leakage'.⁷⁸

HEU can also be found in over 130 HEU-fuelled, civil nuclear research and test reactors around the world, in over 40 countries. Fifty of these research reactors are in or around Europe. Altogether, the fuel cycles of these reactors could account for between 10 and 20 tonnes of HEU.⁷⁹ By another account, some 128 of these reactors and facilities each have 20 kg or more HEU, with 'a few tens more if the threshold is lowered to 5 kg', and the overall global stockpile of non-military HEU could amount to some 200 tonnes.⁸⁰ According to a recent Carnegie Endowment report, global stocks of weapon-usable Pu-239 amount to some 525 tonnes, comprising 275 tonnes of separated civil plutonium (with a further 1,000 tonnes or so in spent fuel), and 250 tonnes of military plutonium.⁸¹ Stocks of civil plutonium will increase, of course, as power-reactor activity continues. The scale of these stockpiles is best understood by noting that the gun-type atomic bomb dropped on Hiroshima in 1945, with a c.12 kt yield, used a football-sized mass of HEU weighing about 50 kg, while the implosion device dropped on Nagasaki used a baseball-sized mass of Pu-239 weighing just 5 kg. With more modern design and engineering techniques, arguably only about 2.5–8 kg of either HEU or Pu-239 would be needed to develop a one-kiloton nuclear device.⁸² Another concern, noted frequently in the literature, is that of collapse of government control of civil and military nuclear facilities and materials in countries such as Pakistan and North Korea.

A so-called Improvised Nuclear Device (IND) could also be produced using much larger quantities of lower-grade, less enriched U-235.⁸³ The device might then 'fizzle' rather than detonate its entire mass instantly and efficiently. But if the resulting explosion were to be equivalent to just one or a few kilotons of TNT rather than tens of kilotons, terrorists could still find this option attractive.⁸⁴ This is, of course, a key point: policy and strategic analysis may have become fixated upon the standards for production of a military nuclear weapon, but these standards might far exceed those necessary for terrorist use. By one account, possibly exaggerated, weapons-grade uranium is so safe to handle that terrorists could initiate a high-yield explosion simply by dropping one half of the HEU mass onto the other: 'if separated HEU is at hand it's a trivial job to set off a nuclear explosion... even a high-school kid could make a bomb in short order.'⁸⁵

The alternative to the purchase or theft of components and materials would be to embark upon an indigenous uranium enrichment programme. But a clandestine uranium recovery, conversion and enrichment programme would require vast financial resources, together with secure and covert research and development facilities and high-capacity electrical power supply. Even if feasible, a programme on this scale would be difficult, if not impossible, to conceal and might therefore be very unattractive to terrorist or radical groups. Plutonium separation is generally understood to be orders of magnitude more difficult than uranium enrichment, requiring a nuclear power infrastructure.

Nuclear Weapons: Delivery Systems

During the Cold War, various means were considered for the delivery of nuclear weapons: missiles of various ranges carrying one or more nuclear warhead, launched from land or beneath the sea; aircraft carrying either free-fall ('dumb') or guided nuclear bombs, or missiles; and artillery and mortar platforms for short-range nuclear weapons. There was even a shoulder-launched nuclear missile which, when launched, would seemingly have had such short range as to be suicidal for its operators. There were also (perhaps apocryphally) some 'suitcase' or 'rucksack' bombs built by the Soviet Union which may still be circulating on the black market.⁸⁶ With the exception, perhaps, of the last device, Cold War-style nuclear weapons were designed and engineered to be sufficiently durable to withstand heavy handling in an urgent military logistics system and on the battlefield. Military-grade nuclear weapons were also designed with very close command and control in mind (hence the invention of permissive action links – PALs), and were expected to be sufficiently well engineered so as to be both reliable and predictable in effect.

For a terrorist group, of course, many of these design expectations would be superfluous, as would be the requirement to ensure durability on the battlefield and penetration of an enemy's complex military defence systems. A terrorist group would, conceivably, be content with a much less sophisticated device, would be attacking open, civilian targets rather than well-defended military sites, and would be unlikely to be constrained by relational, mutual deterrence. Thus for a terrorist group a much less durable but therefore simpler nuclear weapon could be delivered in a variety of utilitarian ways: by truck, train, aircraft, ship and, perhaps, at the exotic end of the wide range of possibilities, by hot air balloon. Another alternative might be to eschew nuclear weapons development and delivery altogether, and instead 'deliver' an attack on a nuclear power station, using conventional means (such as a large proximate explosion or the direct impact of an aircraft) to cause catastrophic breakdown of the reactor and its subsequent destruction.⁸⁷ According to one analyst, a nuclear power station 'contains more than a thousand times the radiation than that released in an atomic bomb blast'.⁸⁸

Nuclear Weapons: Consequences of Attack

A successful attack on or in the United Kingdom using a nuclear weapon would be immediately recognizable; few people can be unfamiliar with images of 'mushroom clouds' over Japan in 1945 and over test sites subsequently. The effects of a nuclear explosion have been well documented and would be unmistakable:

1. *Blast*. Some 50 per cent of the total energy release will be in the form of explosive blast. Massive static overpressures (millions of atmospheres) will be caused, and huge winds (dynamic overpressures) will push rapidly outwards. Subsequently, a 'blowback' effect will be encountered, as pressures equalize and powerful winds are sucked back towards the centre. Buildings and structures will be crushed. Very large objects and debris will become flying objects, causing further death, injury and damage.

2. *Thermal radiation*. Approximately one-third of the total energy yield will be in the form of thermal radiation: a flash of heat and light. People looking directly at the source of the explosion will suffer a degree of flashblindness, depending on the size of the device and their distance from it. Skin burns will also result. At the core of the explosion, the temperature will reach tens of millions of degrees centigrade, vaporizing people and materials. Further from the heart of the explosion, intense fire storms will be caused.

3. *Radiation*. Some 15 per cent of the total energy yield will be in the form of direct nuclear radiation, caused by the isotopes within the device. Indirect nuclear radiation will be caused by radioactive pollution of the blast site and surrounding area, and by fall-out from the debris plume or mushroom cloud.

4. *Electro-magnetic pulse (EMP)*. EMP will cause massive disruption of electrics and electronics. Unless 'hardened' to military standards, communications systems will be particularly vulnerable and will be burned out.⁸⁹

Overall, the immediate effects of a nuclear explosion would be complete, uncompromising damage and destruction over a large area. In some respects, the completeness of the event at its centre would simplify the recovery task; there would be nobody to recover and treat and nothing to repair at the site of the explosion. Further from the centre, of course, the situation would be very different, as casualties mount and fires rage, and emergency services have to contend with collapsed or damaged infrastructure, and high levels of radiation pollution. For emergency services, public authorities and for the public at large, the total failure of communication systems could only compound the problem. The long-term health consequences of a nuclear attack would also present challenges, depending upon the type and strength of the weapon and the level of pollution caused. Finally, a nuclear attack would also cause long-term damage, particularly if used against a financial, commercial or industrial centre.

Nuclear Weapons: Utility

The utility of nuclear weapons for terrorist groups is a subject of some controversy: opinion is divided over whether a terrorist group (assuming it could acquire or construct a nuclear weapon) would choose to make use of such a device, and for what reason. To some extent, this position echoes the long-standing consensus that even terrorists will acknowledge the taboo against the use of nuclear weapons. Certainly, it remains difficult to imagine a nuclear weapon occupying a place in the traditional terrorist's armoury; use of a nuclear weapon would go well beyond any established notion of purposive terrorism, of terrorism as a form of bargaining and negotiation. Since the unilateral use of nuclear weapons by the United States in 1945, thinking about nuclear weapons has been decidedly and consistently relational. That is to say, consideration of the use or threatened use of nuclear weapons has always been influenced by an assessment of the adversary's response to (or anticipation of) such a posture. This reticence is unusual – historically, an innovation in weaponry has generally been seized upon with alacrity for the advantage it might confer upon the side which deploys it first – and can be explained partly by a practical sense of the damage and destruction likely to result from nuclear use, and partly by a sense that use of a nuclear weapon crosses some final moral threshold.

During the Cold War, nuclear weapons were widely understood to have become a category of their own; not 'weapons' in the usual sense, but massively destructive non-weapons held in that category by the mutual decision not to use them. By choosing to break the taboo against nuclear use, a terrorist group would find that it has entered into a strategic calculus of which it has no experience and over which it can exert little if any control. The Cold War has left governments of nuclear-armed states with few options and little nuance as far as the response to nuclear use is concerned. It is intuitively difficult to imagine a government subject to a nuclear attack describing the situation as anything other than all-out war, and just as difficult to imagine that judgment being questioned. Rather than negotiation with the group or individuals responsible, a nuclear-armed government's response is likely only to be one of 'massive retaliation', as envisaged in early Cold War doctrine, against the perpetrators and their hosts and supporters.

But the difficulty arises, of course, when traditional terrorism gives way to so-called 'expressive terrorism', and when the object of nuclear weapon use would be not to negotiate but simply to destroy. For terrorist individuals and groups driven by some religious, millennial or apocalyptic vision, the massive and hugely symbolic impact of a unilateral, 'spectacular' nuclear strike could be precisely their goal. Furthermore, the destruction of themselves and everything associated with them in the retaliatory attack which followed their nuclear attack might be a prospect to be accepted, if not welcomed. What, then, would be the point of launching a nuclear counter-attack against such perpetrators, other than to provide for them the martyrdom they seek? Quite apart from the massive human cost of such an attack, the rationale for a punitive nuclear response falls away when account is taken of the likely size and scale of the organization carrying out the attack; would a group of a few hundred people dispersed across a wide area, and perhaps even among several countries, really be a suitable target for a retaliatory nuclear strike? If not, and if the decision is taken instead to pursue the terrorists with conventional military means, then the terrorists will have gained whatever benefit they envisage from a nuclear attack, without a substantial change in their circumstances, since they would have expected to be pursued by conventional military forces in any case.

The prospect now begins to loom of a nuclear weapon state being self-deterred when contemplating the wisdom of a nuclear response to a limited nuclear attack. The capacity to deter is no better for a non-nuclear weapon state; a conventional military response to a nuclear attack would be of a scale and intensity with which terrorist groups are already familiar, and it is not clear that a nuclear weapon state allied to the victim would contemplate a nuclear release on behalf of its ally, even if the deterrent or punitive value of such an act were clear. Surprisingly perhaps, the 'post-modern' terrorist begins to assume a good deal of initiative in this scenario; the rewards of nuclear use might be perceived as maximal, with the attendant risks minimal (or, at least, unchanged).

Nuclear Weapons: Sample Scenarios

There have been many attempts to model the effects of a nuclear attack upon an undefended 'soft' target such as a city. One recent estimate is that a 10 kt nuclear bomb exploded over a city area (in this case Manhattan) could result in 500,000 deaths and \$1 trillion in economic cost.⁹⁰ The 'Black Dawn' exercise, conducted in May 2003, addressed a scenario of a similar order of magnitude: the detonation over Brussels of a relatively simple gun-type nuclear device, using 40–60 kg of 90 per cent HEU, producing a 10 kt blast with associated effects. The immediate effect of the explosion was estimated for scenario purposes to be 40,000 deaths and a further 300,000 injuries. Another 40,000 deaths would be caused by downwind radiation hazard within 12 hours, and a further 2,000 within 48 hours. Physical destruction would be complete within a radius of 350 metres, with severe damage out to 2 km. The electro-magnetic pulse would destroy unprotected electrical and electronic systems with 3 km of the blast site. Communications would be inoperable. Roads, airports, rail and other infrastructure would be destroyed or severely damaged. The economic cost of the attack was estimated for the scenario to be 'incalculable'.⁹¹ The scenario of an attack upon a nuclear power station has also been modelled. In 1981 a US study estimated that such an attack carried out with an explosive-laden aircraft could cause 130,000 deaths.⁹² Subsequent improvements in reactor design and construction might alter this calculation, although it should be borne in mind that many reactors operating in 1981 still function today.

Nuclear Weapons and Terrorism: Assessment

A nuclear attack using even a relatively small and straightforward gun-type device would cause very extreme harm; the exposure pathways for modern Western societies with their heavily developed and complex cities appear almost limitless. Of course, risk is assessed in terms not only of consequences but also of probability. Yet with consequences on a scale described above, assessments of the probability of such an attack seem almost superfluous; it might be *improbable* that a terrorist organization could either design and manufacture, or acquire a nuclear weapon, and then deliver it, but even the slightest *possibility* that this could happen would entail massively disproportionate consequences. In other words, the risk of terrorist use of nuclear weapons, as traditionally calculated, could scarcely be higher. For Western governments the risk is of such a magnitude that worst-case analysis seems not only unavoidable but also appropriate.

But it might even be that too much is made of the scientific and engineering difficulties associated with acquiring and using a nuclear weapon. Perhaps these constraints do not, after all, limit the probability of terrorist use of a nuclear weapon, or at least not sufficiently? Many scientists and analysts have expressed the concern that nuclear weapon design, materials and engineering have all become commodities, more or less available to those determined enough to acquire them. If this concern is well-grounded, the prospect of terrorist acquisition of a nuclear weapon becomes less a matter of risk assessment than of threat in the more traditional sense, with a nuclear weapon representing a capability waiting to be used, the vulnerability to which would be very high. As well as capability, threat assessment is a calculation of intention; it is known that al-Qaeda has long been interested in acquiring or developing a functioning nuclear weapon, and that Osama bin Laden has declared it a 'religious duty' for al-Qaeda to acquire nuclear weapons.⁹³ By one account, had the Taliban regime not been ejected from Afghanistan, and had al-Qaeda managed to remain relatively unmolested in that country, they would 'eventually' have acquired nuclear weapons.⁹⁴ On these grounds, and in spite of any technical and engineering difficulties, nuclear terrorism might best be described as a 'realistic threat'.⁹⁵ Other analysts describe this possibility in even starker terms: 'Terrorist acquisition of nuclear weapons poses the greatest single threat to the United States.'⁹⁶

6 CONCLUSION

Each of the CBRN categories offers a different portfolio of availability, delivery systems and effects, and overall perceived utility. A well-funded terrorist group, particularly one with a long-term vision of conflict and with the intention not to bargain with an adversary but to inflict as much death and destruction as possible, might well be attracted to the most sophisticated chemical, biological and nuclear weapons, for all the technical and logistical difficulties associated with such devices. Even if only a remote possibility, the effects of such an attack would be devastating and clearly cannot be ignored. But to concentrate on this level of threat might be to perpetuate the Cold War assumption that those interested in WMD or CBRN must inevitably be drawn to the most powerful and sophisticated end of the spectrum. The core observation of this paper is that terrorist groups would not necessarily need a huge, Cold War-style effort to be effective. If the threshold of success is lowered, as it would be for many terrorist groups, then small, relatively simple chemical, biological, radiological and possibly even nuclear weapons could all prove tempting and, crucially, could all be perceived as more or less interchangeable means to the desired end. The first three of these weapon categories have each, tellingly, been described as a terrorist's 'weapon of choice', while a nuclear weapon might be described as the 'Rolls Royce option' to which only the wealthiest terrorist organization might aspire. The CBRN system thus offers all that might be required for a range of terrorist groups from the largest to the smallest, from the almost casual to the most determined and organized, and from the poorest to the best funded.

As far as countering the CBRN danger is concerned, each category will require a tailored approach. Thus, concern over chemical weapons might prompt further efforts to regulate toxic industrial hazards; worry about biological devices might lead to closer regulation of culture collections; the radiological hazard might suggest that more should be done to find and secure so-called 'orphan sources'; and the deep fear of nuclear use by a terrorist group might increase the pressure to improve standards of fissile material accounting and control. But each category must also be seen as a subset of the larger CBRN problem; too much of an emphasis in one CBRN area, at the expense of the others, might prompt adversaries to take a line of lesser resistance, exploiting the redundancy evident in the CBRN system. Anything other than a comprehensive approach to the CBRN problem could also be dangerously self-delusory. Intelligence sources and even public anxiety might prompt policy-makers to focus upon this or that category. But if a surge of activity in one area generates a sense of security on the part of the public and the political elite, its real effect could be precisely the opposite of what was intended as adversaries are prompted to exploit other means and select other targets. The final element of the CBRN system is the response to attack. Terrorists expect a targeted population to panic, thus magnifying the effect of any attack. Yet while a terrorist attack using CBRN would certainly be terrible for all those affected, in most cases the broader impact could be governed by the quality of the public reaction. There is a strong case, therefore, for retaining the initiative in that part of the CBRN system which is largely beyond the reach of terrorists, by ensuring a proportionate, non-panicked public response to an attack. It follows that the CBRN threat should be understood as well and as widely as possible, and it is with that goal in mind that this paper has been written.

Notes

- ¹ The Convention on the Prohibition of the Development, Production, Stockpiling and Use of Chemical Weapons and on their Destruction. The CWC was opened for signature in 1993 and came into force in 1997. Within ten years of entry into force (i.e. by 2007), all declared weapons and production facilities are to be destroyed. Russia declared a stockpile of 40,000 tonnes, the complete eradication of which has not yet been achieved.
- ² Sarin, probably the most commonly discussed CW agent, is extremely toxic; the lethal dose can be as little as 0.5 milligrams.
- ³ Hydrocyanic (or Prussic) acid (AC) is a non-persistent agent, in the form of a colourless liquid with an odour of almonds or marzipan. AC can be lethal within minutes of inhalation.
- ⁴ Sulphur mustard or 'H', also known as yperite. Although non-persistent, mustard can persist in soil in the right conditions for months if not years. Distilled or thickened sulphur mustard is known as HD. 'Dusty mustard' is a more persistent, particulated form of H, distributed by a powdered carrier such as Fuller's earth.
- ⁵ With its odour of new-mown hay, phosgene was first used by the Germans in December 1915, in Flanders. By some accounts, phosgene was the most lethal chemical weapon used during World War I. Phosgene is now a major, bulk-produced industrial chemical; almost 2 billion kg were produced in 1999 alone.
- ⁶ CS gas, or O-chlorobenzylidene malononitrile, has often been used in riot and crowd control by police and security forces. Although recovery from CS inhalation is generally complete, victims endure great discomfort, and some can suffer very serious breathing problems.
- ⁷ N. Bloomfield, 'WMD Terrorism: The Future', *Military Medical Technology* (Online edition, 8/6, October 2004: www.military-medical-technology.com/print_article.cfm?DocID=656). Acute exposure to high levels of MIC can be extremely toxic. Most of the fatalities at Bhopal were probably caused by pulmonary oedema.
- ⁸ 'Chemical weapons ban: now for the hard work', *New Scientist*, 23 January 1993.
- ⁹ D. Bennett, 'Terrorists and Unconventional Weapons: Is the Threat Real?', *Low Intensity Conflict & Law Enforcement* 12/1, Spring 2004, p. 30.
- ¹⁰ B. Kellman, 'Bridling the International Trade of Catastrophic Weaponry', *The American University Law Review* 43/3, 1994, p. 762.
- ¹¹ S. Martin, 'CBN Weapons and Iraq: Lessons for Threat Assessment, Disarmament and Nonproliferation', in P. Cornish (ed.), *The Conflict in Iraq, 2003* (London: Palgrave Macmillan, 2004), p. 177.
- ¹² The standard antidote to nerve agent poisoning is atropine, usually administered with an oxime. The antidote must be administered very rapidly if it is to be effective.
- ¹³ 'UK chemical attack foiled', CNN.com, 6 April 2004. Osmium tetroxide is a highly toxic, corrosive chemical used for 'fixing' or staining in electron microscopy.
- ¹⁴ 'Spain: Al Qaida planned chemical attack', United Press International/*Washington Times* (web edition), 3 May 2005.
- ¹⁵ See <http://cbwinfo.com/Chemical/Blood/AC.shtml>. See also R. Hutchinson, *Weapons of Mass Destruction: The No-Nonsense Guide to Nuclear, Chemical and Biological Weapons Today* (London: Weidenfeld & Nicolson, 2003), pp. 186–7.
- ¹⁶ Martin, 'CBN Weapons and Iraq', p. 180.
- ¹⁷ Bennett, 'Terrorists and Unconventional Weapons', p. 31. According to Smithson and Levy, it could take terrorists, using 'a basement-sized operation', very many years to produce enough nerve agent to kill 10,000 people in the open air; A.E. Smithson and L. Levy, *Ataxia: the Chemical and Biological Terrorism Threat and the US Response* (Washington, DC: Stimson Center, October 2000), p. 279.
- ¹⁸ F. Barnaby, *The Role and Control of Weapons in the 1990s* (London: Routledge, 1992), pp. 87–8.
- ¹⁹ The smallpox virus – *variola* – has been eradicated from nature, and there have been no known natural outbreaks of the disease since the late 1970s. Smallpox is highly contagious, affects only humans and can be spread by aerosol/droplet or contact. In an unvaccinated population, the typical rate of mortality would be about 30%. See <http://www.cbwinfo.com/>. Arguably, the eradication of smallpox in nature has only served to increase its potency as BW: few medical staff are now trained to recognize and respond to smallpox infection, and herd and specialist immunity are low as a result of the abandonment in 1980 of systematic vaccination. It is now possible that 75% of the world's population would be susceptible to infection by smallpox, while global vaccine stocks are thought to be sufficient for just 10% of the world's population. Smallpox could thus be an ideal, very large-scale bioterror 'weapon of mass effect'.
- ²⁰ Plague, caused by the bacillus *Yersinia pestis*, has a variety of forms: bubonic, pneumonic, sylvatic and septicaemic. Plague is extremely infective, and the very rare pneumonic plague distributed by aerosol could be a preferred terrorist BW: the pneumonic variety is more infective than the bubonic, with an extremely high mortality rate, and it can be fatal within as little as 1–2 days (2–19 days for bubonic plague). See <http://www.cbwinfo.com>.
- ²¹ Ebola fever is a viral haemorrhagic disease. Sporadic outbreaks of Ebola occur naturally in parts of Africa. Ebola virus is relatively stable, highly contagious, fatal in 50–90% of cases, and there is no vaccine. Ebola can be transmitted zoonotically from primate populations. Its value as a bioweapon is unproven, however, as weaponization has not been demonstrated. However, it is believed that Aum Shinrikyo attempted to recover the virus from Central Africa.
- ²² Dengue fever is viral and is not often fatal, although its haemorrhagic variant can be more so.
- ²³ Anthrax is caused by the bacterium *Bacillus anthracis*. The disease occurs naturally in cows and other animals. It can

be transmitted zoonotically, from infected animals to humans, but it is not contagious. Anthrax can be prepared and stored as a dormant bacterial spore. Infection can occur through ingestion, inhalation or cutaneous exposure. The anthrax attacks in the United States, between 4 October and 20 November 2001, saw 22 cases of confirmed infection. Half of these cases were of inhaled infection, and half of cutaneous infection. Of the former, five victims died. The anthrax strain used has been identified (the Ames strain) but its exact source, and the identity of those responsible for dispersing it, remain a mystery; see A. Kelle and A. Schaper, 'Terrorism using biological and nuclear weapons', *PRIF Report*, Peace Research Institute Frankfurt, No. 64, 2003, p. 7.

²⁴ Tularemia, caused by the bacillus *Francisella tularensis*, is also known as 'Rabbit fever' or 'Deer fly fever'. Tularemia is extremely infective, with only a small dose necessary to ensure onset of disease. Of those exposed to the bacterium, 90–100% would develop the disease, with a mortality rate of 30–60%. The bacillus is, however, difficult to culture and to produce in quantity. See <http://www.cbwinfo.com>.

²⁵ Otherwise known as paralytic shellfish poisoning, saxitoxin (STX) blocks nerve impulses and can lead to death within minutes if untreated. See <http://www.cbwinfo.com>.

²⁶ *Clostridium botulinum* toxin inhibits the ability of muscles to respond to neural stimuli, causing paralysis and death. Botulinum toxin (botulin or BTX) is the most poisonous substance known, with seven known variants, and can be manufactured by fermentation of *Clostridium botulinum*, a naturally occurring micro-organism. It is claimed that the German urban terrorist group Rote Armee Faction manufactured BTX in the 1980s, and that Aum Shinrikyo attempted a BTX attack on the US Embassy in Tokyo. See <http://www.cbwinfo.com>.

²⁷ Ricin is a powerful, toxic phytoalbumin protein drawn from the beans of the castor plant – *Ricinus communis*. There is no treatment or prophylaxis. Ricin is widely available and easily produced. Worldwide, one million tonnes of castor beans are processed annually to produce castor oil; 5–10% of the waste material from this process is ricin. Ricin can be delivered by inhalation, injection or ingestion. It could be used to contaminate food or water. Ricin could be delivered in aerosol form, having first been freeze-dried. For a general assessment of the lethality and utility of ricin, see S. Sole, 'Why Ricin?', *RUSI Security* 1/5, December 2002/January 2003.

²⁸ Bennett, 'Terrorists and Unconventional Weapons', p. 24 (see note 9 above).

²⁹ Although 'BWC' is in common usage, the full and correct title of the convention is as follows: Convention on the Prohibition of the Development, Production and Stockpiling of Bacteriological (Biological) and Toxin Weapons and on Their Destruction.

³⁰ Bennett, 'Terrorists and Unconventional Weapons', p. 21.

³¹ D. Averre, 'From Co-option to Cooperation: Reducing the Threat of Biological Agents and Weapons', in R. Einhorn and M. Flournoy (eds), *Protecting Against the Spread of Nuclear, Biological and Chemical Weapons: An Action Agenda for the Global Partnership. Volume II: The Challenges* (Washington, DC: CSIS, January 2003), pp. 24–25.

³² Bennett, 'Terrorists and Unconventional Weapons', p. 24.

³³ P. Aldhous, 'The bioweapon is in the post', *New Scientist*, 12 November 2005.

³⁴ A. Oppenheimer, 'Bioterrorism: threat and reality', *Jane's Homeland Security and Resilience Monitor*, December 2005–January 2006, p. 12.

³⁵ The suggestion that Aum Shinrikyo tried to develop or acquire the Q fever virus is challenged in Smithson and Levy, *Ataxia*, p. 76 (see note 17 above).

³⁶ Kelle and Schaper, 'Terrorism using biological and nuclear weapons', pp. 5–6 (see note 23 above).

³⁷ Martin, 'CBN Weapons and Iraq', p. 177 (see note 11 above).

³⁸ Bennett, 'Terrorists and Unconventional Weapons', p. 26.

³⁹ Ibid.

⁴⁰ Kellman, 'Bridling the International Trade of Catastrophic Weaponry', p. 764 (see note 10 above).

⁴¹ *Report to the President of the United States by the Commission on the Intelligence Capabilities of the United States Regarding Weapons of Mass Destruction*, 31 March 2005. See http://www.wmd.gov/report/wmd_report.pdf.

⁴² House of Commons, *Review of Intelligence on Weapons of Mass Destruction* (London: The Stationery Office, July 2004).

⁴³ Bennett, 'Terrorists and Unconventional Weapons', p. 24.

⁴⁴ Both scenarios cited in House of Commons Defence Committee, *The Threat from Terrorism. Volume I* (London: The Stationery Office, 2001), p. xx.

⁴⁵ Martin, 'CBN Weapons and Iraq', p. 194, n. 42.

⁴⁶ Bennett, 'Terrorists and Unconventional Weapons', p. 25.

⁴⁷ House of Commons, *The Threat from Terrorism. Volume I*, p. xx.

⁴⁸ Martin, 'CBN Weapons and Iraq', p. 181.

⁴⁹ Graham Pearson in evidence to House of Commons Defence Committee; House of Commons, *The Threat from Terrorism. Volume I*, p. xix.

⁵⁰ Speculation is rife regarding the possible BW-related uses of genetic and nano-technology. Another possibility could be the modification of naturally occurring bioregulators to produce toxic effects in the host body; see S. Bokan, 'A new breed of weapons – turning the body against itself', *Resilience*, Issue 1, Spring 2004.

⁵¹ See G.L. Epstein, 'Threat Perceptions, Threat Assessments, and US/EU Cooperation in Biodefense', in *New Defence*

Agenda/Chemical and Biological Arms Control Institute, *Countering Bioterrorism: How can Europe and the United States Work Together?* (Brussels, April 2005), p. 53.

⁵² For a balanced and authoritative assessment of the problem of RWs/RDDs see P.D. Zimmerman with C. Loeb, 'Dirty Bombs: The Threat Revisited', *Defense Horizons*, No. 38, January 2004.

⁵³ The Curie (abbreviated Ci) is a unit of measurement of radioactive strength. A one-Ci source is regarded as large, and a 100-Ci source as extremely dangerous.

⁵⁴ Zimmerman and Loeb, 'Dirty Bombs', p. 5.

⁵⁵ *Ibid.*, p. 2.

⁵⁶ Bennett, 'Terrorists and Unconventional Weapons', p. 34.

⁵⁷ Cited in Zimmerman and Loeb, 'Dirty Bombs', p. 2.

⁵⁸ Carnegie Endowment for International Peace, *Universal Compliance: A Strategy for Nuclear Security* (Washington, DC: CEIP), March 2005, pp. 86, 91. The Carnegie Endowment publication draws upon research by D. Albright and K. Kramer; 'Fissile Material: Stockpiles Still Growing', *Bulletin of the Atomic Scientists*, 60/6, November/December 2004. Other studies, however, produce different figures; see Center for International Security and Co-operation, *Preventing Nuclear Proliferation and Nuclear Terrorism: Essential Steps to Reduce the Availability of Nuclear Explosive Materials* (Stanford University, March 2005), p. 27.

⁵⁹ Carnegie, *Universal Compliance* [2005], p. 103; P.C. Bleek, 'Global Cleanout of Civil Nuclear Material: Toward a Comprehensive, Threat-Driven Response', *Strengthening the Global Partnership: Issue Brief No.4* (Washington DC.: Center for Strategic and International Studies, September 2005), p. 1.

⁶⁰ Zimmerman and Loeb, 'Dirty Bombs', p. 5.

⁶¹ *Ibid.*, p. 8.

⁶² In the weeks after the catastrophic destruction of the Chernobyl reactor in April 1986, the town of Pripyat, with its population of 48,000, was evacuated and closed forever.

⁶³ FEMA, 2003, cited in Bennett, 'Terrorists and Unconventional Weapons', p. 22.

⁶⁴ Zimmerman and Loeb, 'Dirty Bombs', p.10.

⁶⁵ Cited in Bennett, 'Terrorists and Unconventional Weapons', p. 36.

⁶⁶ All forms of plutonium are 'weapons-usable'; 'weapons-grade' refers to separated plutonium with an isotopic composition preferred by designers of nuclear weapons. See Bleek, 'Global Cleanout', p. 5, n. 21.

⁶⁷ M. Braemer Maerli, 'Nuclear Terrorism: Threats, Challenges and Responses', *Security Policy Library* (Oslo: Norwegian Atlantic Committee, 8-2002), p. 12.

⁶⁸ Bleek, 'Global Cleanout', p. 11 (see note 59 above).

⁶⁹ The chain reaction should take place in roughly one millionth of a second: Barnaby, *The Role and Control of Weapons*, p. 32 (see note 18 above).

⁷⁰ Kellman, 'Bridling the International Trade of Catastrophic Weaponry', p. 759 (see note 10 above).

⁷¹ *Ibid.*, p. 760.

⁷² Braemer Maerli, 'Nuclear Terrorism', p. 8.

⁷³ *Ibid.*, p. 9.

⁷⁴ Quoted in Bennett, 'Terrorists and Unconventional Weapons', p. 46.

⁷⁵ Barnaby, *The Role and Control of Weapons*, p. 37.

⁷⁶ See A. Newman, 'Cooperative Threat Reduction: "Locking In" Tomorrow's Security', *Contemporary Security Policy*, 22/1, April 2001, p. 84.

⁷⁷ See 'Russia's Loose Nukes: An accounting of recent theft, smuggling, and insecure handling of nuclear material in the former Soviet Union', *The Atlantic Monthly*, December 2004, pp. 74-5.

⁷⁸ "'Black Dawn": Scenario-Based Exercise', report by Center for Strategic and International Studies, Washington, DC, August 2004.

⁷⁹ 'Black Dawn', p. 3. The fuel rods used in non-military research and test reactors tend to be smaller and lighter than those used in nuclear power reactors. Easier to transport and conceal, these fuel rods might be regarded by terrorist groups as an ideal source of HEU.

⁸⁰ Bleek, 'Global Cleanout', p. 1.

⁸¹ Carnegie Endowment for International Peace, *Universal Compliance: A Strategy for Nuclear Security* (Washington, DC: CEIP), June 2004, Draft, pp. 45, 53.

⁸² Bennett, 'Terrorists and Unconventional Weapons', pp. 41, 43.

⁸³ A nuclear explosion could in theory be achieved using U-235 enriched to as little as 20%, but such a device would require hundreds of kilogrammes of U-235. See Bleek, 'Global Cleanout', p. 11.

⁸⁴ Bennett, 'Terrorists and Unconventional Weapons', p. 42.

⁸⁵ Luis W. Alvarez, quoted in Braemer Maerli, 'Nuclear Terrorism', p. 10 (see note 67 above). The idea that one mass of HEU could be dropped onto another to create a chain reaction is disputed; see Kelle and Schaper, 'Terrorism using biological and nuclear weapons', p. 21 (see note 23 above).

⁸⁶ In September 1997 it was claimed that Russia had mislaid no fewer than 100 'rucksack' bombs, each with a potential yield of one kiloton; Kelle and Schaper, 'Terrorism using biological and nuclear weapons', p. 30.

⁸⁷ For a discussion of this scenario see C.D. Ferguson and W.C. Potter, *The Four Faces of Nuclear Terrorism* (New York: Routledge, 2005), chapter 5.

⁸⁸ Bennett, 'Terrorists and Unconventional Weapons', p. 42.

⁸⁹ Hutchinson, *Weapons of Mass Destruction*, pp. 111–13 (see note 15 above). T.K. Mayers, *Understanding Weapons and Arms Control: A Guide to the Issues* (Washington, DC: Brassey's, 1991), pp. 131–3.

⁹⁰ Bennett, 'Terrorists and Unconventional Weapons', p. 39.

⁹¹ 'Black Dawn' (see note 78 above).

⁹² Bennett, 'Terrorists and Unconventional Weapons', p. 37.

⁹³ 'Black Dawn'. See also Braemer Maerli, 'Nuclear Terrorism', p. 8; and Kelle and Schaper 'Terrorism using biological and nuclear weapons', pp. 28–9.

⁹⁴ D. Albright quoted in B. Zellen, 'Nuclear terrorism: re-thinking the unthinkable', *Intersec*, 15/10, October 2005, p. 309.

⁹⁵ Bennett, 'Terrorists and Unconventional Weapons', pp. 22, 38.

⁹⁶ Carnegie, *Universal Compliance* [2004], p. 25.

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