INTERNATIONAL COURT OF JUSTICE

OBLIGATIONS CONCERNING NEGOTIATIONS RELATING TO CESSATION OF THE NUCLEAR ARMS RACE AND TO NUCLEAR DISARMAMENT

(Marshall Islands *v.* United Kingdom)

ANNEXES

TO

MEMORIAL
OF
THE MARSHALL ISLANDS

Volume I

16 March 2015

ANNEX 1 – Hansard, HL Deb, 28 October 1996, vol. 575, col. 134, http://hansard.millbanksystems.com/lords/1996/oct/28/address-in-reply-to-her-majestys-most

It used to be said that Ukraine was the touchstone of Russia's acceptance of the end of the empire. I believe that still to be true. I also believe that Ukrainian independence and prosperity are a measure of our determination to help to create a lasting and peaceful new intra-European matrix of relationships and that as such they merit our very particular attention.

4.25 p.m.

Lord Carver: My Lords, I intend to limit my remarks to two issues of foreign affairs and defence which are closely linked and to what was said by the noble Earl, Lord Jellicoe. They are the elimination of nuclear weapons and the enlargement of NATO.

During the past year I have been a member of the Canberra Commission on the Elimination of Nuclear Weapons, established by the previous Australian Government but given the continued support of their successor. Our mandate was to, "develop ideas and proposals for a concrete and realistic programme to achieve a world totally free of nuclear weapons"." We presented our report to the Australian Prime Minister on 14th August and his Government published it on that day. His foreign minister stated that we had carried out our mandate successfully and that our report was realistic, practical and constructive. He presented it to the UN General Assembly on 30th September.

In our report we listed the many reasons why it is urgent that a major effort should be made now for a real, genuine and unequivocal commitment by the declared nuclear weapon states to the target of total elimination and for them to demonstrate that by a number of steps which we listed. Why is it urgent? First, the destructiveness of nuclear weapons is so great, and their use so catastrophic, that they have no military utility against a comparably equipped opponent other than the belief that they deter such an opponent from using his nuclear weapons. Therefore, their elimination would remove that justification for their retention. Their use against a non-nuclear opponent is politically and morally indefensible, as history has shown.

Secondly, it is urgent because the indefinite deployment of the weapons carries a high risk of their ultimate use intentionally, by accident or by inadvertence. We are lucky that since 1945 no nuclear weapon has been exploded, except in tests, either intentionally or by accident. But there were occasions when the world came close to it, notably in the Cuban crisis. Furthermore, there have been some 100 accidents involving US Air Force aircraft carrying nuclear weapons which could have had disastrous consequences but, fortunately, did not. We owe that good fortune to the fact that nuclear weapons have been held only by nations with strong and efficient governmental machinery and access to the latest technology. Today, with the break-up of the Soviet Union and the actual and potential proliferation of nuclear weapons to states, or even possibly to groups within states which could not be so described, the risk of intentional or accidental use is higher. So long as nuclear weapons exist, and certainly if their possession proliferates, that risk will not only continue but will probably increase.

Thirdly, it is urgent because the possession of such weapons by some states stimulates other nations to acquire them or

ANNEX 2 – J. Rotblat, *Science and Nuclear Weapons: Where Do We Go From Here? (The Blackaby Papers)* (Abolition 2000 UK, No. 5 2004) p. 7, http://www.abolition2000uk.org/Blackaby%205.pdf

The flawed doctrine of extended deterrence

On the other hand, there remains the de facto nuclear strategy of extended deterrence, which implies the indefinite existence of nuclear arsenals.

Since the end of the Cold War, the actual US nuclear strategy has been increasingly orientated towards the use of nuclear weapons, along the lines originally advocated by General Groves.

Immediately after the end of the Cold War, the US policy, supported by many NATO countries, envisaged the use of nuclear weapons as a last resort only, which meant against an attack with nuclear arms. But the 1994 Nuclear Posture Review, under the administration of President Clinton, for the first time made explicit mention of the possible use of nuclear weapons in response to an attack with chemical or biological weapons.

The current US Nuclear Posture Review goes further still, and makes nuclear weapons the tool with which to keep peace in the world.

If this is the purpose of nuclear weapons, then they will be needed as long as disputes are settled by recourse to military confrontation, in other words, as long as war is a recognized social institution. Such a policy is unacceptable in a civilised society on many grounds: logical, political, military, legal, and ethical. In this paper I am mainly concerned with the last two, legal and moral, but I will deal briefly with the others.

US and NATO nuclear policy is self-defeating on logical grounds. If some nations - including the most powerful militarily - say that they need nuclear weapons for their security, then such security cannot be denied to other countries which really feel insecure. Proliferation of nuclear weapons is thus the logical consequence of this nuclear policy. The USA and its allies cannot prevent the acquisition of nuclear weapons by other countries while retaining them for themselves. The policy of extended deterrence undermines the non-proliferation policy.

There is yet a further aspect of the logical argument which strikes at the very basis of deterrence. This is the assumption that both sides in a dispute think and behave rationally; that they are capable of a realistic assessment of the risks entailed in a contemplated action.

This would not be the case with irrational leaders. Even a rational leader may behave irrationally in a war situation, facing defeat, or may be pushed into irrational action by mass hysteria, or when incited by religious fanaticism or nationalist fervour. Deterrence would certainly not apply to terrorists, who have little respect for human life on either side of a conflict.

The policy of extended deterrence is unacceptable on political grounds. It is highly discriminatory in that it allows a few nations - in practice, one nation - to usurp to themselves certain rights, such as policing the world by imposing sanctions on nuclear proliferators, or directly threatening them with military action: such action should be the prerogative of the United Nations. Indeed, it defies the very purpose of the United Nations, an organisation set up specifically for the maintenance of international peace and security.

The policy of extended deterrence also means a permanent polarization of the world, with some nations being offered protection by a powerful nuclear state; while others may either be "protected" by another nuclear state, or have no protection at all.

The policy is not credible on military grounds in relation to terrorist attacks. As the events of September 11th have shown, a major threat to security comes from terrorist groups, a threat which includes the use of all kinds of weapons of mass destruction, including nuclear ones.

ANNEX 3

ANNEX 3 – D. Blair, 'UN nuclear watchdog: Trident is hypocritical', *Daily Telegraph*, 20 February 2007
http://www.telegraph.co.uk/news/uknews/1543248/UN-nuclear-watchdog-calls-Trident-hypocritical.html

Mahmoud Ahmadinejad, the Iranian president, has rejected a looming UN deadline to suspend uranium enrichment, saying it would not halt the sensitive nuclear activity as a precondition to talks.

In a speech broadcast on state television, Mr Ahmadinejad said: "We say to them [the West]: how can your enrichment factories continue to work when you are asking for a suspension of our activities?"

In a lecture at the London School of Economics, Mr ElBaradei said: "They are told nuclear weapons are counter-productive because they do not protect your security.

"But when they look to the big boys, what do they see? They see increasing reliance on nuclear weapons for security, they see nuclear weapons being continually modernised."

He also condemned the "unfairness" of a world in which nine countries seek to maintain their monopoly of nuclear weapons.

"How do they expect this system of haves and have nots to be sustainable? How do I go to country X and say 'you should keep your obligation not to develop nuclear weapons', when the big powers are making no progress towards their obligations for disarmament?"

The nuclear non-proliferation treaty, which came into effect in 1970 and which Mr ElBaradei is legally obliged to enforce, bans all signatories from using atomic power for military purposes.

In addition, the declared nuclear powers are obliged to disarm — but no deadline is given for this to take place.

Mr ElBaradei said that Britain cannot "modernise its Trident submarines and then tell everyone else that nuclear weapons are not needed in the future".

Iran continues to enrich uranium — a process which could create the material for a nuclear bomb — in defiance of UN resolutions.

The Security Council has set a deadline of tomorrow for Iran to halt this work, and Mr ElBaradei is due to meet Ali Larijani, Iran's chief nuclear negotiator, in Vienna today.

"My assessment of the risk of Iran is that it's not an imminent danger for tomorrow," Mr

ANNEX 4 – Statement by Hon. Mr. Phillip Muller, Minister for Foreign Affairs Republic of the Marshall Islands, UN High Level Meeting on Nuclear Disarmament 26 September 2013, http://www.un.org/en/ga/68/meetings/nucleardisarmament/pdf/MH_en.pdf

perspective on the Raratonga treaty. We express again our eventual aspirations to join with our Pacific neighbors in supporting a Pacific free of nuclear weapons in a manner consistent with international security.

Chair.

Disarmament comes with political will – and we affirm and welcome bilateral progress in this regard, including between the United States and Russia. We urge all nuclear weapons states to intensify efforts to address their responsibilities in moving towards an effective and secure disarmament.

The Marshallese people should be the very first group to alert the United Nations to our deeper purpose – that no nation and people should ever have to bear witness to the burden of exposure to the devastating impacts of nuclear weapons. The UN cannot – and must not – repeat such mistakes; we must rise to take on the challenge of international courage.

ANNEX 5 – Letter dated 22 June 1995 from the Permanent Representative of the Marshall Islands to the United Nations, together with Written Statement *of* the Government of the Marshall Islands, http://www.icj-cij.org/docket/files/95/8720.pdf

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itself. Land is considered security in the Marshall Islands customs and mores; in fact, a common saying: "Without land a Marshallese is nobody–it is land that makes a person Marshallese" suggests the Bikinians and Ronglapese are nobody as long as their lands are un-inhabitable. The severity of this assertion can only be understood by the Bikinians particularly as several of their islands were vaporized during the tests.

With a total of only 170 square kilometers of land, Marshall Islands views this loss of lands as a severe renting of their cultural fabric. This will never be compensated for by those responsible for their destruction. Mindful of this land constraint of land for settlement, Ronglapese and Bikinians have been forced to reside in the two urban centers as well. This in turn has cause a major concern as Ebeye, on of these urban centers, a 66 acre island, housed a population of 9500. This is a major increase from its original population of 16 persons.

Other social problems associated with the overcrowding in the urban centers are major hurdles to overcome today.

4. Marshall Islands interest in nuclear disarmament

Given its extensive first hand experience with adverse impacts of nuclear weapons, Marshall Islands decision to ratify the Nuclear Non-Proliferation Treaty this year is understandable. This objective of the treaty of "the cessation of the manufacture of nuclear weapons, the liquidation of all their existing stockpiles, and the elimination from national arsenals of nuclear weapons" is wholly consistent with Marshall Islands' foreign policy of peaceful co-existence as well as with the overarching goal of the international community to achieve global peace.

5. The need for a Court Opinion

Given the legal and moral implications attached to the use or threat of use of nuclear weapons, and owing to the international community's goal for achieving global peace, this issue presses on the need to consider it in legal terms to achieve total consistency with other legally binding agreements which call on the international community to a common undertaking.

On this very issue, Marshall Islands is of the view that the use or threat of use of nuclear weapons is not permitted under international law. It has been clearly documented in the Marshall Islands and elsewhere where nuclear testing has been conducted that the severity such tests have on health and the environment are enormous.

Additionally, any use of nuclear weapons violate laws of war including the Geneva and Hague Conventions and the United Nations Charter. Such laws

ANNEX 6 – T. Ruff, "The health consequences of nuclear explosions," in B. Fihn, ed., *Unspeakable suffering – the humanitarian impact of nuclear weapons* (Reaching Critical Will, 2013), http://www.reachingcriticalwill.org/images/documents/Publications/Unspeakable/Unspeakable.pdf

The health consequences of nuclear explosions

Dr. Tilman A. Ruff

Introduction and context: global health on a knife-edge

Nuclear weapons constitute the greatest immediate threat to global survival, health and sustainability. While the total number of nuclear weapons has been reduced from their 1986 peak of 70,000 to 19,000 now, their capacity to produce a global catastrophe jeopardizing the survival of complex life forms is undiminished. Retention of nuclear weapons makes their eventual use inevitable.

A fundamental requirement of responsible public policy is a firm basis in evidence: in this case understanding the physical, biological and ecological consequences of nuclear weapons. The physical realities at the heart of nuclear dangers are that the physical processes inside an atomic weapon and a nuclear reactor are fundamentally similar; that both increase the radioactivity present in the starting materials at least 1 million times; and that fissile materials will be both toxic and weapons-usable for geological periods that make the timeframes of human institutions irrelevant. Therefore a sound policy approach must be based on primary prevention and the inherent dangers of nuclear weapons and fissile materials, and not the changing complexion of political leaders, alliances, governments, or societies. However, evidence of the effects of nuclear detonations has frequently not been collected, or has been covered-up or disregarded by governments in subservience to the myths that nuclear weapons can be used to enhance security and serve legitimate military purposes. The relentless trend of accumulating scientific evidence about the consequences of use of nuclear weapons has been that the stakes are even higher than previously understood; the more we know the worse it looks.

A brief history of medical evidence regarding nuclear weapon effects

The first foreign doctor to arrive in Hiroshima after the nuclear bombing was ICRC delegate Dr Marcel Junod, whose telegrams make chilling reading. On 30 August 1945 he reported:

> *visited Hiroshima 30th conditions appalling. City wiped out 80% all hospitals destroyed or seriously damaged inspected 2 emergency hospitals conditions beyond description. Effect of bomb mysteriously serious. Many victims apparently recovering suddenly suffer fatal relapse due to decomposition of white blood cells and other internal injuries now dying in great numbers. Estimated still over 100,000 wounded in emergency hospitals located surroundings sadly lacking bandaging materials medicines.*[1]

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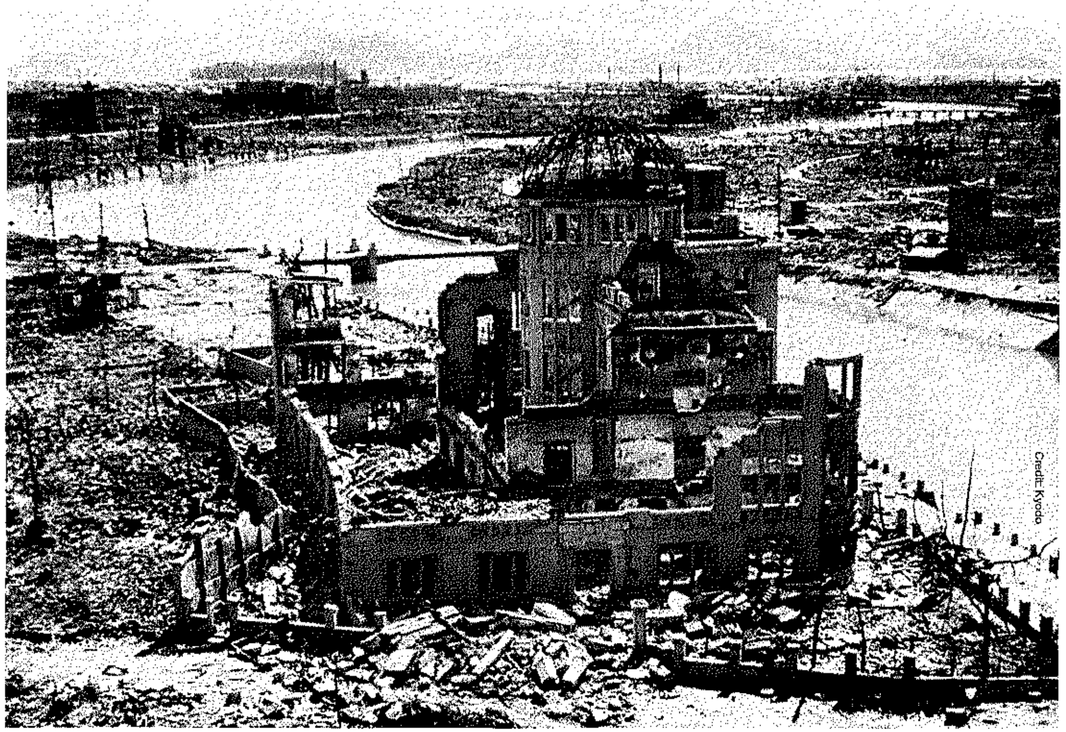

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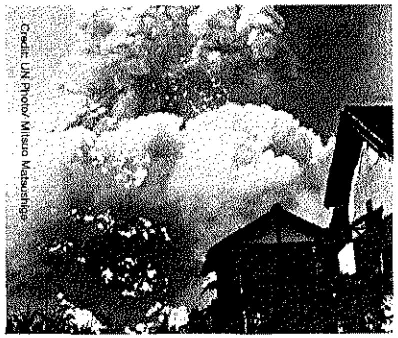
On 5 April 1950, the International Committee of the Red Cross (ICRC) called on all states to take "all steps to reach an agreement on the prohibition of atomic weapons," noting "such arms will not spare hospitals, prisoner of war camps and civilians. Their inevitable consequence is extermination, pure and simple [...] Their effects, immediate and lasting, prevent access to the wounded and their treatment." [2]

The nuclear bombings of Hiroshima and Nagasaki demonstrated the devastating multiple and synergistic health effects of nuclear explosions,[3] and the persistent effects of ionising radiation.[4] Nuclear test explosions -conducted by all the nuclear armed states—2060 in all to date—were used principally to evaluate and develop new nuclear weapons, but also to study the effects of nuclear explosions on people, other animals, buildings and other infrastructure. Nuclear test explosions were shown to cause harmful radiation exposures to military and civilian test personnel and downwind communities, and global radioactive fallout was ubiquitous. In the 1950s, prominent physicians like Albert Schweitzer and Benjamin Spock called for an end to nuclear weapons and testing. Rising levels of strontium-90 in deciduous teeth of children worldwide generated concern and protests which helped drive the conclusion in 1963 of the Partial Test Ban Treaty, which banned above ground nuclear test explosions by the USA and USSR. France continued atmospheric nuclear explosions until 1974 and China till 1980.[5]

In 1962, a group of physicians in Boston published a series of articles in the *New England Journal of Medicine* on the medical consequences of a thermonuclear attack on the United States, and the impossibility of any meaningful medical response.[6-10] These reports were the first of their kind by independent physicians. The great majority of reprint requests came from the US Department of Defense. In the 1980s, largely based on official reports on nuclear weapons effects[11-12], a series of reports and books documented in harrowing detail the medical dimensions of nuclear weapons. Some of these were produced by concerned physicians and their associations[13-15], some by national medical associations[16] and national institutes of science and medicine[17-20].

On 22 May 1981, the World Health Assembly (WHA)—the body representing health ministers worldwide which governs the World Health Organization (WHO)—adopted Resolution WHA 34.38, on "The role of physicians and other health workers in the preservation and promotion of peace as the most significant factor for the attainment of health for all". The Resolution requested the WHO Director-General to create an international expert committee to assist WHO's contribution to the prevention of nuclear war. The report of the International Committee of Experts in Medical Sciences and Public Health was considered by the WHA in 1983, and published as *Effects of nuclear war on health and health services* by WHO in 1984.[21] The report concluded that: "It is obvious that no health service in any area of the world would be capable of dealing adequately with the hundreds of thousands of people seriously injured by blast, heat or radiation from even a single 1-megaton bomb [...] the only approach to the treatment of the health effects of nuclear explosions is [...] the primary prevention of atomic war."

In May 1983 the WHA endorsed the Committee's conclusion that "it is impossible to prepare health services to deal in any systematic way with a catastrophe resulting from nuclear warfare, and that nuclear weapons constitute the greatest immediate threat to the health and welfare of mankind". A second WHO report in 1987 addressed new evidence on radiation effects, firestorms and climatic effects of multiple nuclear detonations and affirmed the earlier conclusions.[22]


Credit: UN Photo/ Mitsuo Matsushige

These reports were important in the world's lead technical health agency for the first time authoritatively documenting the health and environmental consequences of plausible scenarios for use of nuclear weapons. They made a vital contribution to educating the world's medical community, public, and decision-makers about the catastrophic consequences of any use of nuclear weapons, the impossibility of any effective medical response to the effects of even one nuclear weapon exploded on a population centre, and the imperative for primary prevention of nuclear war. They provided an important stimulus to nuclear disarmament and for the end of the Cold War. In 1993 the WHA was the first UN body to request an advisory opinion from the International Court of Justice on the legal status of the threat and use of nuclear weapons. However, requests by the World Health Assembly in 1987 (Resolution WHA 40.24) for WHO to continue investigation of the health effects of nuclear war and for the Director-General to report periodically to the Assembly on progress in this field have not been acted upon.[23]


Credit: UN Photo/ Eiichi Matsumoto

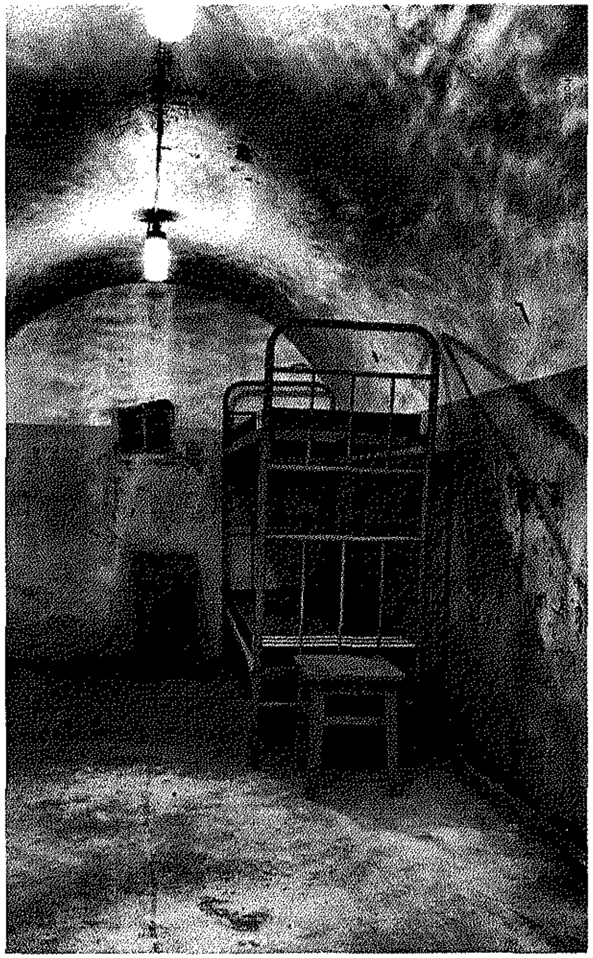
In more recent years, IPPNW physicians have published a number of further studies[24], including of the health impacts of accidental launch against US cities of 48 100kt warheads[25], 75% of those then on a single Russian Delta-IV submarine, and the effects of a Hiroshima size bomb on a major urban centre such as New York[26,27] or Bombay.[28] In 2007, the City of Hiroshima published a report of a committee of experts examining various scenarios for possible nuclear attack on Hiroshima and recommending how the city should respond to the predicted damage.[29] It did so because under a 2004 national law concerning the protection of the civilian population in situations of armed attack, nuclear attack is listed among the attack scenarios. When the Japanese government failed to respond to Hiroshima's request for a national approach to scenarios, effects and countermeasures, the City undertook its own study. The Committee concluded: "It is not possible to protect civilians from nuclear attack. To protect civilians, there is no measure other than to prevent a nuclear weapons attack from occurring [...] To prevent the use of nuclear weapons, there is no other way than to abolish nuclear weapons themselves."

One area in which there has been recent attention to the effects of nuclear weapons is in relation to concerns about nuclear terrorism.[30] This has occurred particularly in the years since the terrorist attacks on New York and Washington in 2001, and has been particularly evident in the USA. A recent example is an inter-agency report coordinated by the US Department of Homeland Security which considers the effects and response to a 10-kt nuclear explosion in the centre of Washington DC.[31,32] Such reports typically assume a single isolated event with normal functioning of services and infrastructure outside the immediately affected area.

However in general, there has over the past two decades been a widespread and continuing neglect of research, documentation of updated evidence, policy analysis, discussion, public and professional education, and professional evidence-based advocacy around the medical implications of nuclear weapons and the impotence of response measures other than primary prevention. An editorial in the medical journal *The Lancet* three years ago lamented that the medical and public health attention to the threat posed by nuclear weapons has lapsed badly in relation to its magnitude and urgency, noting that "it is over a decade ago now since *Lancet* published anything remotely relevant to nuclear weapons as a threat to health. Such complacency has been a serious error."[33] However neither *The Lancet*, nor any other high circulation medical journal, has since remedied this error. This is extraordinary and demands attention in the face of what has been authoritatively identified at the highest level as the greatest immediate threat to human health and welfare.

The effects of nuclear weapons

The effects of nuclear weapons are both qualitatively and quantitatively unique. It has been estimated that in World War II, all the explosives utilised by all sides amounted to 3 million tons (3-Mt) of high explosive equivalent, and that all explosives used in all previous wars amount to something over 10-Mt.[21] In comparison, the largest nuclear test explosion ever conducted, on 30 October 1961 at Novaya Semlya was 50-Mt. The largest warheads currently deployed are on Chinese DF-5A land-based missiles, which are up to 5-Mt in size.[34]



Modern warfare has seen a trend for an increasing proportion of casualties to be civilians, and caused indirectly. For example in the First World War, it is estimated that only around 5% of deaths were among civilians. By the Second World War, this was estimated to have increased to 50%. In the Viet Nam War more than 90% of deaths were of civilians, and in most conflicts in recent decades more than 80% of all deaths have been civilian.[35] Beginning in the latter part of the First World War, escalating during the Japanese occupation of China, and increasing extensively in the Second World War, the indiscriminate bombing of civilians—especially through aerial bombardment of cities—and destruction of key life supporting infrastructure became widespread. The latter includes energy and water supplies and distribution, sewage disposal, and transport and communications systems; in effect this tactic is a form of "weapon of mass destruction in slow motion". Such destruction of life-supporting infrastructure disproportionately affects the most vulnerable in a population, including young children, pregnant women, the elderly, and those with chronic illness. Use of nuclear weapons would not only bring the ultimate in indiscriminate devastation in its intensity and extent to the wider biosphere and its life-supporting functions, but would also add unique, indiscriminate, persistent, and trans-generational health harm through ionising radiation.

UN Photo/ Hajime Miyatake

Nuclear weapons early direct effects include blast, heat causing burns and igniting massive fires, initial radiation, induced radioactivity, radioactive fallout, and electromagnetic pulse. The extent of the damage varies with a wide variety of factors including the height of detonation, time of day, atmospheric conditions, terrain and infrastructure such as buildings. The extent of blast damage is greatest for airbursts; while in a groundburst the fireball touching the ground sucks up large volumes of earth and debris and instead maximizes radioactive fallout.[22] Any nuclear detonation can be expected to cause profound and largely uncontrollable psychological, social, economic, and political effects, and dangers of nuclear retaliation and escalation which would be global in scope.

Blast

Typically about half the energy released in a nuclear explosion is in a colossal blast wave, travelling at supersonic speed. Injuries are caused directly by the pressure wave (e.g. trauma to lungs and other internal organs, eardrum rupture) but more indirectly, by objects which have been turned into missiles, by people being turned into missiles until they collide with other objects, or collapse of structures. The human body can withstand roughly twice the atmospheric pressure (about 100 kPa), but an overpressure of 35kPa would be associated with winds of 260 km/h, fatally hurling people from buildings or against walls[21,22] (wind speeds over 120 km/h are of hurricane force). Blast would smash vehicles, fuel and other chemical tanks; rupture gas and other pipelines; bring down power cables; cause electrical short-circuits; damage chemical and industrial plants, releasing toxic substances into air, ground, and water; make streets impassable; and cause widespread fires.

Heat

The temperature of a nuclear fireball is in the range of 1 to 100 million °C, and about one third of a nuclear bomb's energy is released as a pulse of heat travelling at the speed of light, causing both direct (flash) burns to any living thing exposed, and flame burns due to fires ignited over a wide area. Anyone who reflexively glanced at the fireball would be at risk of flash blindness and retinal burns. After the Marshall Island nuclear explosions, small animals 555 km away were found with retinal burns. As occurred in Hiroshima and following the intensive aerial bombing during the Second World War of Hamburg, Dresden, and Tokyo, simultaneous ignition of numerous fires *over a wide area in cities with their high fuel densities would* produce a firestorm, or coalescing superfire. A rising column of hot gases would suck in air, creating hurricane force winds, large areas with ground temperatures of 800 °C, consuming all flammable materials and available oxygen. No one could survive in such a conflagration, and any underground shelters would become crematoria. While the lethal area (the area within which the number of people surviving is equal to the number killed outside the area) for a blast following a 1-Mt bomb—a typical "strategic" nuclear weapon—would be about 100 km2, the lethal area from a superfire caused by the same single bomb would be about 350 km^2.[22] That is, the number of acute deaths caused by fire would be 3–4 times that caused by blast. Burns are difficult and highly demanding of medical resources and personnel to treat. The United States has about 1760 hospital beds dedicated to specialized care of burn victims; 580 of which are typically unoccupied on any day.[31] A single nuclear explosion could produce tens or hundreds of thousands of burned victims.

Radiation

An initial pulse of neutrons and gamma rays emitted from a nuclear explosion irradiates all living things directly exposed, and neutrons also induce (relatively short-lived) radioactivity in soil and in building and other materials which are not normally radioactive. Nuclear fission (in a nuclear bomb or a nuclear reactor) produces about 300 different radioactive substances, with different decay rates and emissions. Local fallout downwind of a nuclear explosion is greatly increased in a groundburst where the fireball touches the ground and sucks up large amounts of debris, which becomes radioactive. Radioactive products injected into the troposphere (lower atmosphere, where our weather occurs) tend to move with the wind and come down with rain and snow in a band of similar latitude to where the explosion occurred, with hot spots due to deposition by rain and snow. Particularly with larger weapons, radioactive particles reaching the stratosphere (upper atmosphere, beyond the weather) circulate the globe, descending over years as global fallout. The lethal area from superfire following a 1 Mt airburst of about 450km^2 is dwarfed by the area of 5500km2 which under an idealized steady wind of 24km/h, would be blanketed by a cumulative radiation dose of 2 Gray (Gy) from gamma rays alone over about the first day.[14,36] This is roughly comparable to the estimated LD-50 (the dose which kills half of those exposed to it) of 2.5 Gy at the body surface estimated for the survivors of the Hiroshima bomb; and lower than the dose of around 6 Gy which is the LD-50 for acute radiation exposure pertaining under normal conditions in previously healthy people with access to good medical care.[17,22]

Ionising radiation is intensely biologically injurious not because it contains extraordinarily large amounts of energy, but because that energy is packaged and delivered to cells in large packets. The *large complex molecular chains, especially of DNA, that define to* a considerable extent who we are, and are both our most precious inheritance and the most vital legacy we pass on to our children, are particularly vulnerable to disruption by these large packets of energy. The result is that a dose of ionizing radiation lethal to a human being can contain no more energy than the heat in a sip of hot coffee.

Ionising radiation in doses over 250 milliSievert (mSv) can cause acute radiation sickness and at least over 100 mSv a variety of both reversible and persistent effects in different organs, including an increase in cardiovascular and other chronic, non-cancer diseases. At all doses, without any threshold below which there is no effect, including at doses too low to cause any short-term symptoms, radiation exposure increases the long-term risk of cancer for the rest of the life of those exposed. The most recent published data from studies of Hiroshima and Nagasaki survivors confirm a linear dose-response relationship between radiation dose and cancer risk, with no threshold.[37] The overall increase in risk of solid cancer incidence (occurrence) is about one in 10,000 (and about half that for cancer deaths) for each 1 mSv of additional radiation exposure.[38] The risk for leukemia (blood cancer) is about 10% of this.[38]

Radiation risk however, is not uniform. Infants are about four times as sensitive to radiation cancer-inducing effects as middle-aged adults.[38] A single X-ray to the abdomen of a pregnant woman, involving a radiation dose to the fetus of about 10mSv, has been shown to increase the risk of cancer during childhood in her offspring by 40%.[38,39] Females are overall at close to 40% greater cancer risk for the same dose of radiation as males, and this difference is greatest in young children.[38] Women who are carriers of BRCA1/2 gene mutations, which put them at high risk of developing breast cancer, have recently been shown to have heightened sensitivity to increased cancer risk from exposure to radiation.[40] Other genetic markers of increased vulnerability to cancer induction from radiation almost certainly exist but largely remain to be identified.

A very consistent and continuing trend in our understanding of radiation health effects has been that the more we know, the worse it looks. Radiation risk estimates and radiation protection standards have always been raised, never lowered. New evidence continues to emerge of radiation health effects beyond those expected. Some recent examples include:

- *The largest study to date of nuclear industry workers, conducted by the International Agency for Research on Cancer and involving over 400,000 workers in 15 countries, produced estimates of cancer risk 2–3 times higher than linear extrapolation from findings in atomic bomb survivors.[41] These findings are not supportive of the reduced harm often assumed to apply for a given radiation dose delivered over a longer rather than a shorter period of time.*
- *German Childhood Cancer Registry data over 24 years demonstrate compelling evidence of an increased risk of childhood leukemia with proximity of residence to a normally-operating nuclear power plant. For children under five years living within 5 km of a nuclear plant, the risk of leukemia is more than doubled and excess risk extends to more than 50 km away.[42] Data from several other countries are consistent with these findings.[43]*
- *Evidence that population exposures across broad regions to low radiation doses from global fallout from nuclear test explosions and the Chernobyl disaster are associated with fewer female babies being born relative to males.[44]*
- *The estimated cancer risk associated with exposure to radon gas was doubled in 2009. Radon is the largest ubiquitous source of environmental radiation exposure and second only to tobacco as a cause of lung cancer.[45,46]*

There has been some confusion and misinterpretation about the genetic consequences of ionizing radiation exposure across generations. It is clear that radiation is a powerful cause of genetic damage. It is also clear that many genetic effects are heritable, that genetic influences on disease occurrence are often complex, interact with environmental factors, and affect multiple body systems. Previously, studies of children born to those exposed to the nuclear bombings in Hiroshima and Nagasaki have not demonstrated an increase in diseases attributable to radiation-induced mutations. However, there is extensive evidence of radiation-induced transmissible mutations in other animals, and there is no reason to believe humans are immune to such harm[38], and there is now emerging evidence indicating an increased risk of leukemia in children whose parents were exposed to the atomic bombings in Japan.

Electromagnetic pulse (EMP)

An intense, brief radiowave pulse produced by a nuclear explosion could cause extensive disruption to electrical equipment. The pulse from an explosion 100 km high would cover an area of 4 million sq km; that from an explosion 350 km high could, for example cover most of North America with a voltage a million times greater than lightning. This energy would be taken up by vast numbers of metallic objects, including electricity cables, telephone lines, railways, and antennae; and transmit this to computers and electronic equipment and circuitry essential to telecommunications, computer systems, transport networks, supplies of water and electricity, and much commerce and trade. Modern industrial, commercial, and urban functioning is highly dependent on electronic and computer equipment.

While an EMP would not be directly hazardous to people, a recent US government commission to assess the EMP threat concluded that an EMP "has the capability to produce widespread and long-lasting disruption and damage to the critical infrastructures;" that "a single EMP attack may seriously degrade or shut down a large part of the electric power grid [...] possibility of functional collapse of grids beyond the exposed area" and that if significant parts of the electrical power infrastructure were lost "the consequences are likely to be catastrophic, and many people may ultimately die for lack of the basic elements necessary to sustain life in dense urban and suburban communities."[47]

Modern health care is highly dependent on computers and electrically-operated equipment. In EMP simulation studies, 65% of electronic medical equipment was damaged.[47] Loss of radio and telephone communications would severely hamper any emergency response efforts.

The report from an investigation conducted between 2004-2007 by the US National Academy of Sciences of the vulnerability of the US electricity delivery system to terrorism and how to reduce it was classified in its entirety; most of it being made available publicly only in August 2012. National electricity grids are highly vulnerable to EMP, blast, fires, and other effects of nuclear explosions, and extensive and prolonged outages could be expected.[48]

Combined effects and casualty estimates

A variety of ways have been used to estimate the casualties resulting from nuclear explosions in or over cities, including an overly simplistic focus on blast effects (overpressure model); adding prompt radiation and flash burn casualties; and using the zone of confluent superfires (conflagration model). Some estimates model sheltering provided by buildings and estimate evacuations. In the past decade, most government attention to understanding the effects of nuclear explosions has been in relation to the effects of a single 1–20 kt range nuclear weapon exploded by a non-state "terrorist" organisation. In Hiroshima in 1945 approximately 70% of victims had combined injuries involving combinations of burns, traumatic wounds, and irradiation.[21] Such combinations of multiple injuries and of different types escalate the medical resources required for effective treatment and increase the likelihood of complications and death for the patient.

Remarkably little publicly available work has been undertaken to review and update data on the effects of more widespread use of nuclear weapons by states in light of changing population demographics, changing population distributions and nature of buildings and combustible material in cities in different global regions, and changing nuclear arsenals and targeting strategies. This is true across local, regional, and national governments as well as groupings of states and international organisations. The author is not aware, for example, of any report on any aspect of the effects of nuclear weapons produced by any UN agency since the 1987 WHO report.[22]

On the one hand, more sophisticated and updated methods and estimates of the effects of nuclear explosions would not materially alter the fact that those effects would be so catastrophic that there does not exist anywhere—nationally or internationally—any capacity to ameliorate the consequences in any meaningful way and primary prevention remains the only appropriate response. On the other hand, the remarkable dearth of updated evaluations of nuclear explosions in response to the most acute threat to global health and survival cannot but constitute wilful neglect of the magnitude and implications of those effects, of proper accountability of government, and of the ongoing democratic and humanitarian need for wide public education, understanding, and engagement to drive evidence-based public policy on nuclear weapons. This neglect of evidence and the reality of nuclear weapon effects exacerbates the dangers of their continued possession, deployment, and threats of use. If governments have undertaken studies of the effects of nuclear weapons that have not been made public, they have an obligation to do so.

Illustrative estimates of the effects of a nuclear weapon in the range of the Hiroshima bomb (15-kt) and the Nagasaki bomb (21-kt) include:

- *A 2007 evaluation by a committee of experts convened by the City of Hiroshima estimated that in the first 3–4 months following a 16-kt airburst over the city there would be 66,000 deaths and 205,000 injured persons; and 55,000 deaths, 146,000 injured persons, and up to 402,000 radiation deaths following a surface burst[27];*
- *Estimates of casualties (dead and injured) from a 10-kt improvised nuclear device exploded in the central business district of a major US city range from 150,000 in Los Angeles to 500,000 in New York[49], in the latter with a 12.5-kt explosion estimated to cause 52,000 immediate deaths from blast and heat, 10,000 acute radiation deaths, another 200,000 deaths from 24 hour cumulative radiation, and several hundred thousand cases of radiation sickness not fatal in the short-term.[26]*
- *A Hiroshima-size weapon (15-kt) detonated inside a van in Trafalgar Square in London in the middle of a working day has been estimated to cause 115,000 deaths and another 149,000 casualties[50], without taking into account the potentially wider effects of fire conflagration and dispersed radioactive fallout;*
- *In crowded central Mumbai, with population densities exceeding 100,000 people per km², following a 15-kt airburst up to 866,000 acute deaths and up to 2.1 million injured persons are estimated[23]; and*
- *Adapting casualty by distance data from Hiroshima and Nagasaki, Toon and colleagues estimated casualties in the most densely populated regions of various countries following a single 15 kt nuclear explosion.[51] They found up to between 126,000 (UK) and 760,000 (China) deaths, between 214,000 (UK) and 1,379,000 (Egypt) total casualties following an airburst, and up to 111,000 (China) acute radiation fatalities following a groundburst.*

Illustrative estimates of the effects of single larger nuclear explosions include:

- *The 2007 Hiroshima study estimated for a 1-Mt airburst up to 1.16 million acute deaths[27];*
- *A 2011 US Department of Homeland Security report evaluating effects and response needs for a 10-kt groundburst in central Washington, DC estimated—excluding the effects of fires—up to 1.6 million injured persons, including 343,000 people suffering traumatic injuries, 267,000 of them severe, and 201,000 persons suffering acute radiation sickness[31];*
- *A 1.2-Mt nuclear explosion on the Yongbyon nuclear weapons and power facilities in the Democratic People's Republic of Korea would kill more than 500,000 people immediately, with 2 million additional serious casualties[52]; and*
- *Either three 340-kt or a single 1.2-Mt groundburst aimed at Iran's nuclear facilities at Isfahan and Natanz could cause at least 2.6 million immediate deaths, and expose between 10.5 million and more than 35 million people to significant levels of radiation.[53]*

Examples of estimates of the effects of multiple nuclear explosions include:

- *An accidental nuclear attack involving surface explosion of 48 warheads, each 100-kt, carried by 12 of the 16 missiles aboard a single Russian submarine, targeted against key industrial, transportation, financial, and other infrastructure sites in the USA, would cause 6.84 million initial deaths from firestorms alone[28];*
- *262 550-kt warheads targeted on the USA to maximise casualties were estimated to cause up to 100 million immediate deaths from firestorms[4]; and*

Within a distance of 4.7 km in every direction, all living things would die almost immediately-vapourised, crushed, charred, irradiated. 7.5 km in every direction, essentially everyone would be killed or seriously injured. Stretching to out 22.6 km in every direction, everything flammable would ignite, and thousands upon thousands of fires would coalesce into a giant firestorm. Wherever they were, most living thing would die from burns and asphyxiation. Still further out, hundreds of thousands of people would be seriously injured. And everywhere the invisible, silent, lingering danger of radiation would persist.

- *50 15-kt airbursts targeted at urban zones in different countries would produce up to 17.6 million immediate deaths from blast and fires in the case of airbursts, up to 9.3 million similar deaths with groundbursts, and up to 2.6 million short term radiation deaths in the case of groundbursts. The highest number of deaths among the 13 countries evaluated occurred in China, followed by India. The total casualties for China in the case of 50 15-kt airbursts was estimated at 32.2 million; 20.6 million in the case of groundbursts.*[51] *The weapons involved would constitute less than 0.04% of the total explosive yield and less than 0.3% of the number of weapons in the global nuclear arsenal.*

A 5-Mt nuclear explosion

In an attempt to make the unique destructive power of nuclear weapons more comprehensible, the health-related effects of a single 5-Mt nuclear weapon exploded over a major city will be described. Such a weapon is the largest known to be currently deployed. The equivalent amount of TNT high explosive would fill a freight train 2414 km long. Sufficient energy would be released by the explosion of such a bomb to turn 5 million tons of ice to steam. Within a thousandth of a second, conditions akin to the centre of the sun would be produced—100 million °C and 100 million atmospheres of pressure in a fireball, which would rapidly expand to 1.8 km across, releasing a massive burst of radiation, heat, light, and blast.

Within a distance of 4.7 km in every direction, winds of 750 km/h and a blast wave over 140 kPa would crush, collapse, or explode all buildings including those of steel and reinforced concrete and turn the debris into missiles with lethal velocity. Glass and steel would melt; concrete would explode. Wherever they were, all living things would die almost immediately—vapourised, crushed, charred, irradiated.

Out to about 7.5 km in every direction, winds of 460 km/h and blast pressures of 80 kPa would break apart concrete and steel buildings and sweep out their walls, floors, and ceilings. Aluminium would be vapourised. Adults would be hurled over 100m at high speed. Essentially everyone would be killed or seriously injured, including by crush injuries, ruptured lungs, transected spinal cords, severe haemorrhage, and deep burns.

As far as 12.3 km in every direction, winds of 260 km/h and blast pressures of 35 kPa would crush wooden and brick buildings including houses, schools, shops, and many factories. People would be hurled 7m. Asphalt would melt. Windows would be fragmented into more than 4000 projectile glass shards per square meter. Glass and other debris would penetrate people like shrapnel. Many people would have ruptured eardrums. In less than 10 seconds the city would be completely devastated.

Stretching to out 22.6 km in every direction, over an area of 1605 km², everything flammable would ignite—wood, paper, clothing, plastics, petrol, and oil from ruptured tanks and cars; all of this would be fuelled further by ruptured gas pipes, downed electricity lines, and leaking chemicals. Within half an hour, thousands upon thousands of fires would coalesce into a giant firestorm 45 km across with temperatures of more than 800°C, sucking in air creating winds of more than 320 km/h, consuming all available oxygen. Wherever they were, every living thing would die from burns and asphyxiation. Shelters would become crematoria.

Still further out, windows would be shattered, buildings damaged, the air filled with broken debris turned into missiles. The streets would be impassable. There would be no ambulances, fire engines or police, no power or communications. People would be trapped under buildings, cars, and fallen debris. Beyond the raging firestorm hundreds of thousands of people would be seriously injured. Crush injuries, fractures, deep lacerations, and internal bleeding would abound. Many would be deaf from ruptured eardrums; many blinded by retinal burns after having glanced reflexively at the fireball. All would be deeply traumatised. Many would lose all will or capacity to function. Everywhere the invisible, silent, lingering danger of radiation would persist. Hundreds of thousands of people would have severe second and third degree burns, requiring the most intensive medical resources and care, but none would be available. Hospitals would have disappeared or be damaged. If they were still standing they would likely have no power or water. Laboratories, operating theatres, sterilisers, ventilators, infusion pumps, cardiac monitors, and other equipment would either be smashed, burned, or not working from the electromagnetic pulse and loss of power. The few who could reach hospitals or clinics would find that most of the doctors, nurses, and other health professionals would be themselves dead or injured. The few not consumed with their own injuries, losses, or loved ones, who might be able to assist, would quickly run out of any medical supplies they managed to salvage. The vast majority of injured people would die alone without so much as a human hand or voice to comfort them and without any relief for their agonising pain.

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Most current nuclear weapons are smaller than a 5-Mt bomb—the most numerous in the US arsenal are between 100- and 455-kt; the most numerous in the Russian arsenal are between 100- and 800-kt.[34] However, multiple smaller nuclear weapons are more efficient at delivering destruction over a wider area, so a single large detonation underestimates the destruction that would be caused by unleashing a large part of the available nuclear arsenals. Recent studies have shown that in nuclear terms "low" yield (Hiroshima size) weapons, if targeted at city centres, can produce 100 times as many fatalities and 100 times as much smoke from fires per kt of explosive yield as high yield weapons.[51]

When the fires ignited by a nuclear explosion had gone out, any survivors, whether injured or not, would likely face a city inhospitable beyond recognition. Safe water, food, shelter, warmth, electricity, fuel, basic goods, assistance, and information would be hard to find. Most of the life-supporting and health-enabling infrastructure and services of modern societies would be severely disrupted. Sanitation breakdown, malnutrition, social disintegration, profound mental trauma, and the ever-present, ongoing, invisible, indiscriminate, and inescapable hazard of radioactivity would combine to fuel increased vulnerability to and spread of endemic and epidemic infectious diseases.

Humanitarian response capacity

Health professional staff, hospitals, and other health care resources are concentrated in urban centres, and would likely be disproportionally affected by a nuclear weapons attack. In Hiroshima, of 300 doctors 270 were reported dead, of 1780 nurses 1654 were dead, and of 140 pharmacists 112 were dead; 42 of 45 hospitals were non-functional.[21] The most recent available US Department of Homeland Security (DHS) assessment of response planning factors following a single 10-kt nuclear groundburst in Washington DC demonstrates the wide gulf that exists between the potential casualties of a single relatively small nuclear explosion and the health care resources available to respond to its aftermath, even in one of the most resource-rich settings (Table).

In Hiroshima, of 300 doctors 270 were reported dead, of 1780 nurses 1654 were dead, and of 140 pharmacists 112 were dead; 42 of 45 hospitals were non-functional[21]

The 2007 City of Hiroshima assessment of another nuclear attack on the city concludes: "no matter how government bodies tried to deal with the situation, the effect would be merely to reduce the casualties on a minute scale."[29] They note that if prior warning could be given to enable people to take shelter indoors, acute

Table: Casualties and health care capacity estimates for a 10-kt ground burst in Washington DC

High consequence scenario 95th percentile

Total injured persons: 1.6 million	National capital region:	
Persons suffering trauma: 343,000	Available hospital beds:	2177
Moderate-severe trauma: 267,000	Available ICU beds:	118
Persons suffering acute radiation sickness: 201,000	Available ventilators:	200
	Unoccupied burn beds:	5
	Available staff:	-
	Nationwide:	
	Unoccupied burn beds: 580 of 1760	
	Unoccupied ICU beds: 9400 of 118,000	

Note: The effects of fires are not included.

casualties may be reduced, and that in areas far removed from ground zero, evacuation may be effective in reducing casualties. Exposure to early radioactive fallout could be reduced by early sheltering and delayed evacuations following a small number of dispersed nuclear explosions, but the gulf between available medical resources—even if they could be effectively accessed in time—and need, even in the United States following a single small nuclear explosion is salutary.

The Hiroshima Committee of Experts concluded unequivocally: "It is not possible to protect civilians from a nuclear weapons attack. To protect civilians, there is no measure other than to prevent a nuclear weapons attack from occurring, whether it be deliberate or accidental. To prevent the use of nuclear weapons, there is no way other than to abolish nuclear weapons themselves."[29]

The substantial civil defence programmes against nuclear attacks that became widespread in the 1950s were discredited and largely abandoned in the early 1980s because of the work of physicians and scientists demonstrating that these programmes were ineffectual, deceptive and wasteful.[55]

The second WHO report (1987)[22] concluded in relation to management of casualties following a nuclear war: "Obviously the health services of the world could in no way cope with such a situation. In sum, in the event of a nuclear war triage would at best be insignificant, rescue work scarcely other than makeshift [...] The great majority of casualties would be left without medical attention of any kind [...] When treatment is ineffective, the only solution available to the health professions is prevention. Prevention is obviously the only possibility in case of a nuclear war."

Members of emergency services, other disaster responders, health care professionals, other personnel providing essential services, and the many who may be called to assist in responses to humanitarian emergencies would face unique dangers and difficulties following any nuclear explosion, with widespread and persistent radioactivity severely complicating and hampering access and relief efforts. Many such roles are normally voluntary, and informed consent is required. Disaster response planning should not be based on unrealistic or frankly fictional assumptions about what is possible following nuclear disaster, and responders should not be expected to do the impossible or place themselves at unacceptable danger.

Recent assessments by senior experts of the Red Cross/Red Crescent movement, the world's largest humanitarian organisation, make clear that there are no international plans or capacity for assisting the victims of nuclear explosions[56,57] The 2011 resolution of the Council of Delegates, the highest governing body of the International Red Cross/Crescent movement, "Working towards the elimination of nuclear weapons", in its first operative paragraph: "emphasizes the incalculable human suffering that can be expected to result from any use of nuclear weapons, the lack of adequate humanitarian response capacity and the absolute imperative to prevent such use".[58]

Members of emergency services, other disaster responders, health care professionals, other personnel providing essential services, and the many who may be called to assist in responses to humanitarian emergencies would face unique dangers and difficulties following any nuclear explosion, with widespread and persistent radioactivity severely complicating and hampering access and relief efforts.

Conclusion: a need for evidence-based policy

Evidence of the unacceptable, catastrophic consequences for the health of the human population in case of any use of nuclear weapons is unassailable. Incontrovertible evidence of unacceptable humanitarian effects has been key to the substantial progress made in banning the use of and eliminating other types of indiscriminate, inhumane weapons – biological and chemical weapons, anti-personnel landmines and most recently cluster munitions. Nuclear weapons are far more indiscriminately destructive than any of these.

As noted above, evidence-based advocacy has repeatedly been effective in relation to nuclear weapons. Public and health professional pressure based on evidence of the widespread presence of radioactive fallout including strontium-90 in the deciduous teeth of children in the 1950s and 60s played a major role in the end of atmospheric nuclear tests; in repeatedly extended Soviet nuclear test moratoriums during the 1980s and the eventual near-complete cessation of nuclear test explosions. Serious discussion at the 1985 Geneva and 1986 Reykjavik summits between General Secretary Gorbachev and President Reagan on the complete abolition of their nuclear arsenals over a 15 year timeframe owes much to the work of scientists and physicians in spreading awareness about the catastrophic consequences of use of nuclear weapons and the impossibility of any effective response short of prevention. This was reflected in the joint statement by Gorbachev and Reagan at their 1985 summit that "[a] nuclear war cannot be won and must never be fought."[59] Gorbachev wrote that the 1980s research on nuclear winter had a great influence on him[60] and that without IPPNW's efforts, the abolition of US and Russian intermediate range nuclear missiles and other disarmament initiatives "would probably have been impossible".[61] Physicians played a significant role in New Zealand's nuclear free status; Prime Minister David Lange saying at the 1986 IPPNW World Congress: "You have made medical reality a part of political reality."[62]

In recent decades there has been widespread deliberate denial of the daily existential threat to global health and survival posed by nuclear weapons. In the last generation, no national government or international agency has produced a comprehensive public report on the effects of use of nuclear weapons, addressing squarely the risks posed to human and global security by current arsenals, or their continued modernisation. On the most acute threat to human health identified by the World Health Organisation, we have nothing like the Intergovernmental Panel of Climate Change, whereby the world's foremost scientific expertise is harnessed to update and analyse the evolving evidence and put it before the public and decision-makers. Thus far, only one government—that of Switzerland—has invested, modestly, in examining, validating, and extending the extensively published and peer-reviewed evidence, generated through the initiative and courage of a small number of independent scientists, on the danger of nuclear famine following use of a tiny fraction of the world's nuclear arsenal. This must change. The biggest challenges deserve the greatest attention. Policies on nuclear weapons must be based on the best evidence regarding their actual effects. Our survival depends on it.

1. International Committee of the Red Cross, *Working towards the elimination of nuclear weapons* (2011), ICRC, No CD/11/4.1,http://www.icrc.org/eng/resources/documents/report/nuclear-background-document-2011-11-26.htm.
2. F. Bugnion, *The International Committee of the Red Cross and Nuclear Weapons: From Hiroshima to the Dawn of the 21st Century, International Review of the Red Cross 87* (2005), no. 859, pp. 511-24
3. Hiroshima-shi Nagasaki-shi Genbaku Saigaishi Henshū Iinkai, *Hiroshima and Nagasaki, the Physical, Medical, and Social Effects of the Atomic Bombings* (1981), New York, Basic Books
4. K. Ozasa, Y. Shimizu, A. Suyama, F. Kasagi, M. Soda, EJ. Grant, R. Sakata, H. Sugiyama and K. Kodama, *Studies of the Mortality of Atomic Bomb Survivors, Report 14, 1950-2003: An Overview of Cancer and Noncancer Diseases* (2012), Radiat Res 177, no. 3, pp. 229-243
5. IPPNW International Commission to Investigate the Health and Environmental Effects of Nuclear Weapons Production, Institute for Energy and Environmental Research, *Radioactive Heaven and Earth : The Health and Environmental Effects of Nuclear Weapons Testing in, on, and above the Earth : A Report of the Ippnw International Commission to Investigate the Health and Environmental Effects of Nuclear Weapons Production, and the Institute for Energy and Environmental Research* (1991), New York London, Apex Press, Zed Books
6. FR. Ervin, JB. Glazier, S. Aronow, DG. Nathan, R. Coleman, N. Avery, S. Shohet and CP. Leeman, *The Medical Consequences of thermonuclear War: I, Human and Ecologica Effects in Massachsetts of an Assumed Thermonuclear Attack on the United States* (1962), New England Journal of Medicine 266, no. 22, pp. 1127-1137
7. DG. Nathan, HJ. Geiger, VW. Sidel and B. Lown, *The Medical Consequences of Thermonuclear War: the Physician's Role in the Post-Attack Period* (1962), New England Journal of Medicine 266, no. 22, pp. 1137-1145
8. S. Aronow, *The Medical Consequence So Fthermonuclear War: III, a Glossary of Radiation Terminology* (1962), New England Journal of Medicine 266, no. 22, pp. 1145-1149
9. PH. Leiderman and JH. Mendelson, *The Medical Consequences of Thermonuclear War: Iv, Some Psychiatric and Social Aspects of the Defense-Shelter Program* (1962), New England Journal of Medicine 266, no. 22, pp. 1149-1155
10. DG. Nathan, HJ. Geiger, and B. Lown, *The Medical Consequences of Thermonuclear War: Introduction* (1962), New England Journal of Medicine 266, no. 22, pp. 1126-1127
11. Congress of the US, Office of Technology Assessment , *The Effects of Nuclear War* (1979), Washington, US Govt. Print. Off.12.S.Glasstone, P.J. Dolan, , *The Effects of Nuclear Weapons* (1977), 3d ed., United States Dept. of Defense, United States Dept. of Energy and United States Defense Atomic Support Agency,Washington, US Dept. of Defense
13. R.Adams and S.Cullen, *The Final Epidemic : Physicians and Scientists on Nuclear War* (1981), Chicago, Educational Foundation for Nuclear Science : Distributed by University of Chicago Press, Marketing Dept.
14. E. Chivian, S. Chivian, RL. Lifton RJ, JE. Mack (eds), *Last Aid : The Medical Dimensions of Nuclear War* (1982), International Physicians for the Prevention of Nuclear War, Congress, San Francisco, W.H. Freeman
15. CK. Cassel, M. McCally and H.Abraham, *Nuclear Weapons and Nuclear War : A Source Book for Health Professionals* (1984), New York, Praeger
16. British Medical Association Board of Science and Education, *The Medical Effects of Nuclear War : The Report of the British Medical Association's Board of Science and Education*, (1983), a Wiley Medical Publication, Chichester, New York, published on behalf of the British Medical Association by J. Wiley.
17. F. Solomon, R. Q. Marston and Institute of Medicine, *The Medical Implications of Nuclear War* (1986), Washington DC, National Academy Press
18. W.Green, T.Cairns, J. Wright , *New Zealand after Nuclear War* (1987), New Zealand Planning Council, Wellington, NZ, New Zealand Planning Council
19. J. Peterson, *The Aftermath : The Human and Ecological Consequences of Nuclear War* (1983), New York, Pantheon Books.
20. J. Peterson (Ed), *The Aftermath: The Human and Ecological Consequences of Nuclear War. A Special Ambio Publication* (1982), Royal Swedish Academy of Sciences, New York, Pantheon Books
21. International Committee of Experts in Medical Sciences and Public Health and World Health Organization, *Effects of Nuclear War on Health and Health Services : Report of the International Committee of Experts in Medical Sciences and Public Health to Implement Resolution WHA34.38*, (1984), Geneva Albany, NY, World Health Organization, WHO Publications Center
22. WHO, *Effects of Nuclear War on Health and Health Services : Report of the Who Management Group on Follow-up of Resolution WHA36.28 : "The Role of Physicians and Other Health Workers in the Preservation and Promotion of Peace"* (1987), 2nd ed, Geneva World Health Organization
23. T. Ruff and I. Helfand, *Humanitarian and Public Health Efforts Are Needed to Eradicate Nuclear Weapons* (2012), Australian and New Zealand Journal of Public Health 36, no. 4, pp. 303-306
24. G. Mutalik, F. Barnaby, P. Taylor and D. Sumner, *Crude Nuclear Weapons. Proliferation and the Terrorist Threat* (1996), IPPNW Global Health Watch, International Physicians for the Prevention of Nuclear War, Cambridge, MA, USA: International Physicians for the Prevention of Nuclear War
25. L. Forrow, BG. Blair, I. Helfand, G. Lewis, T. Postol, V. Sidel, BS. Levy, H. Abrams and C. Cassel, *Accidental Nuclear War-a Post-Cold War Assessment* (1998), N Engl J Med 338, no. 18, pp. 1326-1331
26. I. Helfand, L. Forrow and J. Tiwari, *Nuclear Terrorism* (2002), BMJ 324, no. 7333, pp. 356-9
27. I. Helfand, A. Kanter, M. McCally, K. Roberts, and J. Tiwari, *The Us and Nuclear Terrorism* (2006) Washington DC, Physicians for Social Responsibility
28. M.V. Ramana, *Bombing Bombay? Effects of Nuclear Weapons and a Case Study of a Hypothetical Nuclear Explosion* (1999), International Physicians for the Prevention of Nuclear War, Cambridge, MA, USA
29. Committee of Experts on the Scenarios of Casualties Resulting from a Nuclear Weapons, *Report from the Committee of Experts on the Scenarios of Casualties Resulting from a Nuclear Weapons Attack* (2007), Hiroshima, Hiroshima City Council for Civil Protection
30. PM. Sutton and RM. Gould, *Nuclear and Radiological Weapons* (2012), In Terrorism and Public Health, edited by BS. Levy and VW. Sidel, New York, Oxford University Press, pp. 154-182
31. BR. Buddemeier, JE. Valentine, KK. Millage and LD. Brandt, *National Capital Region Key Response Factors for the Aftermath of Nuclear Terrorism* (2011), Lawrence Livermore National Laboratory, US Department of Energy (Contract No.: LLNL-TR-512111)
32. AL. DiCarlo, C. Maher, JL. Hick, D. Hanfling, N. Dainiak, N. Chao, JL. Bader, CN. Coleman and DM. Weinstock, *Radiation Injury after a Nuclear Detonation: Medical Consequences and the Need for Scarce Resources Allocation* (2011), Disaster Med Public Health Prep 5, Suppl 1, pp. 32-44
33. D. Wolfe, and R. Horton, *A New Era of Nuclear Disarmament for Human Security* (2010), England, Lancet, pp. 173-174
34. SN. Kile, P. Schell, HM. Kristensen, A. Glaser and Z. Mian, *World Nuclear Forces* (2012), Sipri Yearbook 2012, Stockholm International peace Research Institute, Oxford, Oxford University Press pp. 307-50
35. B.S. Levy and Victor W. Sidel, *War and Public Health* (2008), 2nd ed, New York, Oxford University Press
36. J. Rotblat , *Nuclear Radiation in Warfare* (1981), Stockholm International Peace Research Institute, London, Taylor & Francis
37. K. Kodama, K. Ozasa, H. Katayama, RE. Shore, T. Okubo, *Radiation effects on cancer risk in the life span study cohort* (2012), Radiation Protection Dosimetry, vol151(4), pp. 674-676.
38. Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation, *Health Risks from Exposure to Low Levels of Ionizing Radiation: Beir VII, Phase 2* (2006), Washington DC, National Academy of Sciences
39. R. Doll and R. Wakeford, *Risk of Childhood Cancer from Fetal Irradiation* (1997), Br J Radiol 70, pp. 130-9
40. Pijpe, N. Andrieu, DF. Easton, A. Kesminiene, E. Cardis, C. Nogues, M. Gauthier-Villars et al, *Exposure to Diagnostic Radiation and Risk of Breast Cancer among Carriers of Brca1/2 Mutations: Retrospective Cohort Study (Gene-Rad-Risk)* (2012), *British Medical Journal* 345, e5660
41. E. Cardis, M. Vrijheid, M. Blettner, E. Gilbert, M. Hakama, C. Hill, G. Howe, *Risk of Cancer after Low Doses of Ionising Radiation: Retrospective Cohort Study in 15 Countries* (2005), BMJ 331, no. 7508, pp. 77
42. P. Kaatsch, C. Spix, R. Schulze-Rath, S. Schmiedel and M. Blettner, *Leukaemia in Young Children Living in the Vicinity of German Nuclear Power Plants* (2008), Int J Cancer 122, no. 4, pp. 721-6
43. R. Nussbaum, *Childhood Leukemia and Cancers near German Nuclear Reactors: Significance, Context and Ramifications of Recent Studies* (2009), Int J Occup Environ Health 15, no. 3, pp. 318-23
44. H. Scherb and K. Voigt, *The Human Sex Odds at Birth after the Atmospheric Atomic Bomb Tests, after Chernobyl, and in the Vicinity of Nuclear Facilities* (2011), Environ Sci Pollut Res Int 18, no. 5, pp. 697-707
45. *Who Handbook on Indoor Radon : A Public Health Perspective* (2009), Geneva, Switzerland: World Health Organization.
46. International Commission on Radiological Protection, *Icrp Statement on Radon* (2009), ICRP Ref 00/902/09.
47. Commission to Assess the Threat to the United States from Electromagnetic Pulse, *Report of the Commission to Assessthe Threat to the United States from Electromagnetic Pulse (EMP) Attack : Critical National Infrastructures* (2008), Washington DC, US G.P.O.
48. National Research Council, Committee on Enhancing the Robustness, Resilience of Future Electrical Transmission and Distribution in the United States to Terrorist Attack, *Terrorism and the Electric Power Delivery System* (2012), Washington, DC, National Academies Press
49. G.Benjamin, M.G.H. McGeary, S.R. McCutchen and Institute of Medicine Committee on Medical Preparedness for a Terrorist Nuclear Event, *Assessing Medical Preparedness to Respond to a Terrorist Nuclear Event : Workshop Report* (2009), Washington DC, National Academies Press
50. G.J. Evans and Y. Kawaguchi, *Eliminating Nuclear Threats : A Practical Agenda for Global Policymakers* (2009), Canberra, ACT: International Commission on Nuclear Non-proliferation and Disarmament
51. OB. Toon, RP. Turco, A. Robock, C. Bardeen, L. Oman, GL. Stenchikov, *Atmospheric Effects and Societal Consequences of Regional Scale Nuclear Conflicts and Acts of Individual Nuclear Terrorism* (2007), Atm Chem Phys 7, pp. 1973-2002
52. P. Wilk, S. Stanlick and M. Butcher, *Projected Casualties among U.S. Military Personnel and Civilian Populations from the Use of Nuclear Weapons against Hard and Deeply Buried Targets* (2005), Washington DC, Physicians for Social Responsibility
53. Physicians for Social Responsibility, *Medical Consequences of a Nuclear Attack on Iran* (2006), Washington DC, Physicians for Social Responsibility
54. I. Helfand, L. Forrow, M. McCally, and RK. Musil, *Projected Us Casualties and Destruction of Us Medical Services from Attacks by Russian Nuclear Forces. Medicine and Global Survival* (2002), 7(2), pp. 68-76 and *Medicine and Global Survival 7* (2002), no. 2, pp. 68-76
55. J.Leaning, and L.C.Keyes, *The Counterfeit Ark : Crisis Relocation for Nuclear War* (1984), Cambridge, Mass, Ballinger Pub. Co.
56. D. Loye and R. Coupland, *Who Will Assist the Victims of Use of Nuclear, Radiolgical, Biological or Chemical Weapons - and How? International Review of the Red Cross 89* (2007), no. 866, pp. 329-344
57. R. Coupland and D. Loye, *International Assistance for Victims of Use of Nuclear, Radiological, Biological and Chemical Weapons: Time for a Reality Check?* (2009), International Review of the Red Cross 91, no. 874, pp. 329-340
58. Council of Delegates of the International Red Cross and Red Crescent Movement, *Working Towards the Elimination of Nuclear Weapons* (2011), International Committee of the Red Cross; http://www.icrc.org/eng/resources/documents/resolution/council-delegates-resolution-1-2011.htm.
59. R. Rhodes, *Arsenals of Folly : The Making of the Nuclear Arms Race* (2007), 1st ed, New York, Alfred A. Knopf.
60. M. Hertsgaard, *Mikhail Gorbachev Explains What's Rotten in Russia* (2000), Salon, http://dir.salon.com/story/news/feature/2000/09/07/gorbachev/index.html
61. MS. Gorbachev, *Perestroika: New Thinking for Our Country and the World* (1988), New York, Harper & Row
62. D. Lange, *Reflections on the Ending of the Arms Race: New Zealand's Example* (1986), paper presented at the Sixth World Congress of the International Physicians for the Prevention of Nuclear War, Cologne, pp 15-21

ANNEX 7

ANNEX 7 – President Barack Obama, Prague speech, April 5, 2009, https://www.whitehouse.gov/the_press_office/Remarks-By-President-Barack-Obama-In-Prague-As-Delivered

THE WHITE HOUSE

Office of the Press Secretary

FOR IMMEDIATE RELEASE April 5, 2009

REMARKS BY PRESIDENT BARACK OBAMA

Hradcany Square

Prague, Czech Republic

10:21 A.M. (Local)

. . . .

Now, understand, this matters to people everywhere. One nuclear weapon exploded in one city — be it New York or Moscow, Islamabad or Mumbai, Tokyo or Tel Aviv, Paris or Prague — could kill hundreds of thousands of people. And no matter where it happens, there is no end to what the consequences might be — for our global safety, our security, our society, our economy, to our ultimate survival.

Some argue that the spread of these weapons cannot be stopped, cannot be checked — that we are destined to live in a world where more nations and more people possess the ultimate tools of destruction. Such fatalism is a deadly adversary, for if we believe that the spread of nuclear weapons is inevitable, then in some way we are admitting to ourselves that the use of nuclear weapons is inevitable.

Just as we stood for freedom in the 20th century, we must stand together for the right of people everywhere to live free from fear in the 21st century. (Applause.) And as nuclear power — as a nuclear power, as the only nuclear power to have used a nuclear weapon, the United States has a moral responsibility to act. We cannot succeed in this endeavor alone, but we can lead it, we can start it. . . . .

ANNEX 8 – Report and Summary of Findings of the Conference presented under the sole responsibility of Austria, Vienna Conference on the Humanitarian Impact of Nuclear Weapons, 8 to 9 December 2014, http://www.bmeia.gv.at/fileadmin/user_upload/Zentrale/Aussenpolitik/Abruestung/HINW14/HINW14_Chair_s_Summary.pdf

EUROPE
INTEGRATION
FOREIGN AFFAIRS
FEDERAL MINISTRY
REPUBLIC OF AUSTRIA

VIENNA CONFERENCE ON
THE HUMANITARIAN IMPACT
OF NUCLEAR WEAPONS
8-9 DEC. 2014

Vienna Conference on the Humanitarian Impact of Nuclear Weapons
8 to 9 December 2014
Report and Summary of Findings of the Conference
presented under the sole responsibility of Austria

The Vienna Conference on the Humanitarian Impact of Nuclear Weapons took place from 8 to 9 December 2014. It addressed the humanitarian consequences of any use of nuclear weapons, including effects on human health, the environment, agriculture and food security, migration and the economy, as well as the risks and likelihood of the authorized or unauthorized use of nuclear weapons, international response capabilities and the applicable normative framework.

Delegations representing 158 States, the United Nations, the International Committee of the Red Cross, the Red Cross and Red Crescent movement, civil society organisations and academia participated in the Conference.

The UN Secretary General and Pope Francis conveyed messages to the Conference. The President of the ICRC addressed the participants. Hibakusha, the survivors of the nuclear explosions in Hiroshima and Nagasaki, and victims of the effects of nuclear testing also participated in the Conference and gave their testimonies and experiences. Their presence and contributions exemplified the unspeakable suffering caused to ordinary civilians by nuclear weapons.

The Vienna Conference built upon the fact-based discussions at the first and second Conferences on the Humanitarian Impact of Nuclear Weapons, held respectively in Oslo and Nayarit, and contributed to a deeper understanding of the consequences and the actual risks posed by nuclear weapons. Moreover, these further discussions underlined the extreme challenges for humanitarian response in the event of nuclear weapon explosions in populated areas. Furthermore, it presented a "bird's eye view" on international norms and the humanitarian impact of nuclear weapons. Key conclusions from the substantive sessions included the following:

- The impact of a nuclear weapon detonation, irrespective of the cause, would not be constrained by national borders and could have regional and even global consequences, causing destruction, death and displacement as well as profound and long-term damage to the environment, climate, human health and well-being, socioeconomic development, social order and could even threaten the survival of humankind.

- The scope, scale and interrelationship of the humanitarian consequences caused by nuclear weapon detonation are catastrophic and more complex than commonly understood. These consequences can be large scale and potentially irreversible.

- The use and testing of nuclear weapons have demonstrated their devastating immediate, mid- and long-term effects. Nuclear testing in several parts of the world has left a legacy of serious health and environmental consequences. Radioactive contamination from these

ANNEX 9 – M.J Mills *et al.*, "Multi-decadal Global Cooling and Unprecedented Ozone Loss Following a Regional Nuclear Conflict", *Earth's Future Research Paper* 2014, at p. 161, http://climate.envsci.rutgers.edu/pdf/MillsNWeft224.pdf

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Earth's Future

RESEARCH ARTICLE

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Multidecadal global cooling and unprecedented ozone loss following a regional nuclear conflict

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Key Points:

- Impacts of a regional nuclear war are simulated with an Earth system model
- Global cooling following a regional nuclear war could persist for more than 25 years
- Global ozone loss unprecedented in human history is confirmed

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Abstract We present the first study of the global impacts of a regional nuclear war with an Earth system model including atmospheric chemistry, ocean dynamics, and interactive sea ice and land components. A limited, regional nuclear war between India and Pakistan in which each side detonates 50 15 kt weapons could produce about 5 Tg of black carbon (BC). This would self-loft to the stratosphere, where it would spread globally, producing a sudden drop in surface temperatures and intense heating of the stratosphere. Using the Community Earth System Model with the Whole Atmosphere Community Climate Model, we calculate an e-folding time of 8.7 years for stratospheric BC compared to 4–6.5 years for previous studies. Our calculations show that global ozone losses of 20%–50% over populated areas, levels unprecedented in human history, would accompany the coldest average surface temperatures in the last 1000 years. We calculate summer enhancements in UV indices of 30%–80% over midlatitudes, suggesting widespread damage to human health, agriculture, and terrestrial and aquatic ecosystems. Killing frosts would reduce growing seasons by 10–40 days per year for 5 years. Surface temperatures would be reduced for more than 25 years due to thermal inertia and albedo effects in the ocean and expanded sea ice. The combined cooling and enhanced UV would put significant pressures on global food supplies and could trigger a global nuclear famine. Knowledge of the impacts of 100 small nuclear weapons should motivate the elimination of more than 17,000 nuclear weapons that exist today.

1. Introduction

In the 1980s, studies of the aftermath of a global nuclear conflict between the United States and the Soviet Union predicted that airborne particles, such as fine soil and smoke resulting from explosions and fires, could circle the globe, producing "twilight at noon," and cooling the surface for years, in what became known as "nuclear winter" [*Crutzen and Birks*, 1982; *Turco et al.*, 1983; *Pittock et al.*, 1985]. Further studies looked at perturbations to atmospheric chemistry, predicting that odd nitrogen produced by the largest nuclear weapons could loft to the stratosphere, resulting in significant ozone loss, and an "ultraviolet spring" to follow [*National Research Council*, 1985; *Stephens and Birks*, 1985]. Leaders in the United States and the Soviet Union became aware of the global environmental damage of nuclear war and subsequently negotiated treaties that have significantly reduced their nuclear stockpiles from their peak near 65,000 in 1986 to less than 20,000, a decline that continues with further negotiations in recent years [*Robock et al.*, 2007a; *Toon et al.*, 2007, 2008]. Nevertheless, significant numbers of weapons remain, and the number of nuclear-armed states continues to increase.

Since 2007, studies have revisited the issue of global nuclear conflicts with modern global climate models, confirming the severity of the climatic impacts that had been predicted with simple climate models or with short simulations of low-resolution atmospheric general circulation models in the 1980s [*Robock et al.*, 2007a], and raising new concerns about severe global climatic impacts of regional nuclear conflicts [*Robock et al.*, 2007b; *Toon et al.*, 2007; *Mills et al.*, 2008; *Stenke et al.*, 2013]. Even the smallest of nuclear weapons, such as the ~15 kt weapon used on Hiroshima, exploding in modern megacities would produce firestorms that would build for hours, consuming buildings, vegetation, roads, fuel depots, and other infrastructure, releasing energy many times that of the weapon's yield [*Toon et al.*, 2007]. *Toon et al.* [2007] estimated the potential damage and smoke production from a variety of nuclear exchange scenarios, and found that smoke would initially rise to the upper troposphere due to pyroconvection. *Robock et al.* [2007b] examined the climatic impact of the smoke produced by a regional conflict in the subtropics in which two countries each used 50 Hiroshima-size (15 kt) nuclear weapons, creating such urban firestorms. Using the global climate model GISS ModelE (Goddard Institute for Space Studies, New York), they calculated that nearly all the 5 Tg of smoke produced would rise to the stratosphere, where it would spread globally, reducing the global average temperature by 1.25°C for 3–4 years and by more than 0.5°C for a decade. This effect was longer lasting than that found in previous "nuclear winter" studies, because older models could not represent the rise of smoke into the stratosphere. *Mills et al.* [2008] then used a chemistry-climate model to calculate that the concurrent heating of the stratosphere by up to 100°C would produce global ozone loss on a scale unprecedented in human history, lasting for up to a decade.

Recently, *Stenke et al.* [2013] used a third independent model to confirm the major findings of these two previous studies. That study used the chemistry-climate model SOCOL3 to assess impacts on climate and stratospheric ozone for a range of inputs and particle sizes. The study coupled a mixed-layer ocean with a depth of 50 m and a thermodynamic sea ice module to a high-top atmospheric model, which calculated chemistry effects in agreement with *Mills et al.* [2008]. Unlike *Robock et al.* [2007b], the study did not consider active ocean dynamics, and hence could not incorporate the climate effects of changing ocean circulation. The inclusion of only the top 50 m of ocean limits the thermal inertia effects that occur in the presence of a deep ocean, making surface temperature responses too rapid, as the heat content of the deeper ocean is not considered.

Here we present the first study of this scenario with an Earth system model, coupling a chemistry-climate model to interactive ocean, sea ice, and land components.

2. Model Description

2.1. CESM1(WACCM)

We revisit the scenario of nuclear war between India and Pakistan, each side using 50 Hiroshima-size weapons in megacities on the subcontinent, using the first version of NCAR's Community Earth System Model (CESM1), a state-of-the-art, fully coupled, global climate model, configured with fully interactive ocean, land, sea ice, and atmospheric components [*Hurrell et al.*, 2013]. For the atmospheric component, we use the Whole Atmosphere Community Climate Model, version 4 (WACCM4), which is a superset of version 4 of the Community Atmospheric Model (CAM4), and includes all the physical parameterizations of that model [*Neale et al.*, 2013]. WACCM is a "high-top" chemistry-climate model that extends from the surface to 5.1×10^{-6} hPa (~140 km). It has 66 vertical levels and horizontal resolution of 1.9° latitude × 2.5° longitude. WACCM includes interactive chemistry that is fully integrated into the model's dynamics and physics. Heating the stratosphere, for example, feeds back onto chemical reaction rates. Photolysis rates are calculated based on extinction of exoatmospheric flux from overhead ozone and molecular oxygen, and are unaffected by aerosol extinction. WACCM uses a chemistry module based on version 3 of the Model for Ozone and Related Chemical Tracers (MOZART) [*Kinnison et al.*, 2007], tailored to the middle and upper atmosphere. The chemical scheme includes 59 species contained in the O_x, NO_x, HO_x, ClO_x, and BrO_x chemical families, along with CH_4 and its degradation products; 217 gas-phase chemical reactions; and heterogeneous chemistry that can lead to the development of the ozone hole. For our simulations, CESM1 includes the active land, ocean, and sea ice components described by *Lawrence et al.* [2011], *Danabasoglu et al.* [2012], and *Holland et al.* [2012], respectively. The full ocean model extends up to 5500 m in depth, and includes interactive, prognostic ocean circulation. The nominal latitude-longitude resolution of the ocean and sea ice components is 1°, the same as in CESM1(WACCM) simulations conducted as part of phase 5 of the Coupled Model Intercomparison Project [*Marsh et al.*, 2013].

2.2. CARMA

We have coupled WACCM with version 3 of the Community Aerosol and Radiation Model for Atmospheres (CARMA3), a flexible three-dimensional bin microphysics package that we have adapted for the treatment of black carbon (BC) aerosol. This allows the BC to experience gravitational settling, and obviates the implementation of molecular diffusion, which the gas-phase tracers in WACCM experience at high altitudes. CARMA originated from a one-dimensional stratospheric aerosol code developed by *Turco et al.* [1979] and *Toon et al.* [1979] that included both gas-phase sulfur chemistry and aerosol microphysics. The model was improved and extended to three dimensions as described by *Toon et al.* [1988]. Extensive updates of the numerics continue to be made. For this study, we limit BC to one size bin of fixed radius.

As described below, we performed an ensemble of runs assuming a microphysical radius of 50 nm, to be consistent with the optical properties of BC assumed in the model's radiative code, which are derived from the Optical Properties of Aerosols and Clouds (OPAC) software package [*Hess et al.*, 1998]. Our previous studies of BC in the stratosphere from nuclear war and space tourism used these same optical properties, but with a radius for sedimentation that was twice as large [*Mills et al.*, 2008; *Ross et al.*, 2010]. We also conducted one perturbation run using the same 100 nm radius for sedimentation as those previous studies, for comparison in the coupled model.

We do not allow calculated particle populations to change radiatively or microphysically other than by rainout, sedimentation, and transport. The particles are assumed to be completely hydrophilic from the start, and hence are subject to rainout in the troposphere. We assume a mass density of 1 g cm^{-3} for each BC particle, consistent with measurements of atmospheric BC particles collected on filters, which are composed of smaller, denser particles aggregated in fractal formations with spatial gaps [*Hess et al.*, 1998]. As *Toon et al.* [2007] point out, coagulation of BC is likely to form chains or sheets, which would have the same or higher mass absorption coefficients as smaller BC particles. Drag forces would decrease sedimentation of such chains or sheets compared with aerosols that grow as simple spheres. Our neglect of coagulation, assuming a monodisperse distribution of 50 nm radius spheres, should more accurately predict stratospheric lifetime under conditions with fractals than a treatment of growth into larger spheres with faster sedimentation. *Toon et al.* [2007] also indicate that the BC is likely to become coated with sulfates, organics, and other nonabsorbing materials, which could act as lenses, refracting light onto the BC. This effect might increase absorption by ~50%, leading to potentially greater impacts than those we modeled.

2.3. Model Setup

We have performed an ensemble of three "experiment" runs initialized with 5 Tg of BC with 50 nm radius over the Indian subcontinent. A fourth experiment run includes the same mass and spatial distribution of BC, with 100 nm sedimentation radius. We compare these experiment runs to an ensemble of three "control" runs without this additional BC. Each of these seven runs simulated the time period from 1 January 2013 to 1 January 2039, with concentrations of greenhouse gases and other transient constituents changing with time according to the specifications of the "medium-low emissions" Representative Concentration Pathway (RCP4.5) scenario [*Meinshausen et al.*, 2011], a baseline for climate projections. We also tried starting the simulated conflict on 15 May, as was done by *Robock et al.* [2007b] and *Stenke et al.* [2013], and found that the different season did not significantly affect the stratospheric distribution or climatic impact of the BC. Because of the prolonged surface cooling that we calculated, we extended our runs beyond the 10 year span used in previous studies to 26 years.

In the experiment runs, 5 Tg of BC was added to the initial atmospheric condition in a constant mass mixing ratio of 1.38×10^{-6} kg/kg air between 300 and 150 hPa in a horizontal region spanning 50 adjacent model columns roughly covering India and Pakistan. The BC heats the atmosphere to extreme conditions, requiring a reduction of the model's standard time step from 30 to 10 min. Because this reduction in time step produces a significant increase in cloudiness in the model due to dependencies in the cloud parameterization, we reduced the time step consistently in the experiment and control runs. We also tried an alternate approach of increasing the dynamical substepping in the model, but found that the 16-fold increase in the number of substeps required to produce a stable result produced a similar increase in clouds to our original approach. We diagnose the effects of reducing the model time step in section 2.4.

The three members of each ensemble were configured with different initial conditions for the ocean, land, and sea ice components, derived from the ensemble of three RCP4.5 CESM1(WACCM) runs conducted as part of CMIP5 [*Marsh et al.*, 2013]. These components interact with the atmosphere, producing a representation of natural climate variability among the three runs in each ensemble. As we will show, the variability that we calculate within each ensemble is small compared to the differences between the experiment and control ensemble averages, indicating that the effects we calculate are not attributable to model internal variability.

2.4. Model Validation

To understand the effects of changing the model time step on our conclusions, we diagnosed the climate of one of our control runs for years 2023–2038, 16 years starting 10 years after the change in time step, with reference to the climate of the same years from one of the CESM1(WACCM) CMIP5 runs for RCP4.5, the same forcing scenario used in our runs. The effect of increased low clouds is to change the global shortwave (SW) cloud forcing from −55 to −62 W m^{-2}. Observations from Clouds and Earth's Radiant Energy Systems (CERES) Energy Balanced and Filled (EBAF) put this forcing near −51 W m^{-2}, so the change produces a more reflective planet than is observed (A. Gettelman, personal communication). This may lead to an underestimation of the surface cooling anomaly in our calculations, because the effect of extinction in the stratosphere would be reduced if less SW radiation reaches the surface in both our control and experiment runs. At the same time, global longwave cloud forcing increases from 30 W m^{-2} in our CMIP5 run to 34 W m^{-2}. Observations from CERES EBAF put this forcing near 26–27 W m^{-2}, so the change is toward more greenhouse warming from high clouds than is observed. This 4 W m^{-2} increase in cloud forcing partially offsets the surface cooling effects of the 7 W m^{-2} decrease in the SW. The changes in cloud forcing occur mostly in the tropics.

Because we started from an RCP4.5 scenario in 2013, the initial atmosphere is not in radiative balance, but is warming in response to anthropogenic greenhouse gases. The radiative imbalance at the top of the model is 0.977 W m^{-2} in our CMIP5 run for years 2023–2038. The effect of increased clouds is to reduce this by a factor of 10 to 0.092 W m^{-2}, bringing the model close to the radiative balance that would be seen in a steady state, such as the static conditions used for previous nuclear winter calculations. We ran an additional case in which the 5 Tg of BC is added in year 10 of the control run. These calculations confirm that our calculated BC mass, and surface anomalies in SW flux, temperature, and precipitation are not significantly affected by any transient adjustments after the initial change in time step.

We also diagnosed effects on stratospheric chemistry by comparing the ensemble average column ozone from our control runs to the ensemble average from the CESM1(WACCM) CMIP5 runs for the first 6 years after we introduced the change in time step. We found no significant differences in either the global mean or latitudinal distribution of column ozone due to the change in time step. The effects of changing the model time step are relatively minor compared to those of 5 Tg of BC in the stratosphere, which is the focus of our study.

3. Results

3.1. BC Rise and Meridional Transport

As in previous studies of this scenario [*Robock et al.*, 2007b; *Mills et al.*, 2008], the BC aerosol absorbs SW radiation, heating the ambient air, inducing a self-lofting that carries most of the BC well above the tropopause. CESM1(WACCM) has 66 vertical layers and a model top of ~145 km, compared to 23 layers up to ~80 km for the GISS ModelE used by *Robock et al.* [2007b] and 39 layers up to ~80 km for SOCOL3 used by *Stenke et al.* [2013]. As Figure 1 shows, we calculate significantly higher lofting than *Robock et al.* [2007b, compare to their Figure 1b], penetrating significantly into the mesosphere, with peak mass mixing ratios reaching the stratopause (50–60 km) within 1 month and persisting throughout the first year. This higher lofting, in conjunction with effects on the circulation we discuss later, produces significantly longer residence times for the BC than those in previous studies. At the end of 10 years, our calculated visible-band optical depths from the BC persist at 0.02–0.03, as shown in Figure 2. In contrast, Robock *et al.* [2007b] calculate optical depths near 0.01 only at high latitudes after 10 years, a level that our calculations do not reach for 15 years.

3.2. BC Burden, Rainout, and Lifetime

During the first 4 months, 1.2–1.6 of the 5 Tg of BC is lost in our 50 nm experiment ensemble, and 1.6 Tg in our 100 nm experiment, mostly due to rainout in the first few weeks as the plume initially rises through the troposphere (Figure 3a). This is larger than the 1.0 Tg initially lost in the study of *Mills et al.* [2008], which used a previous version of WACCM. This is likely due to the difference in our initial distribution of BC compared to that previous study, which injected 5 Tg into a single column at a resolution four times as coarse as ours. The more concentrated BC in the previous study likely produced faster heating and rise into the stratosphere, mitigating rainout. Our calculated rainout contrasts with the lack of significant rainout calculated by the GISS ModelE [*Robock et al.*, 2007b], which assumes that BC is initially hydrophobic and becomes hydrophilic with a 24 h *e*-folding time scale. The mass burden reaching the stratosphere and impacts on global climate and chemistry in our calculations would doubtless be greater had we made

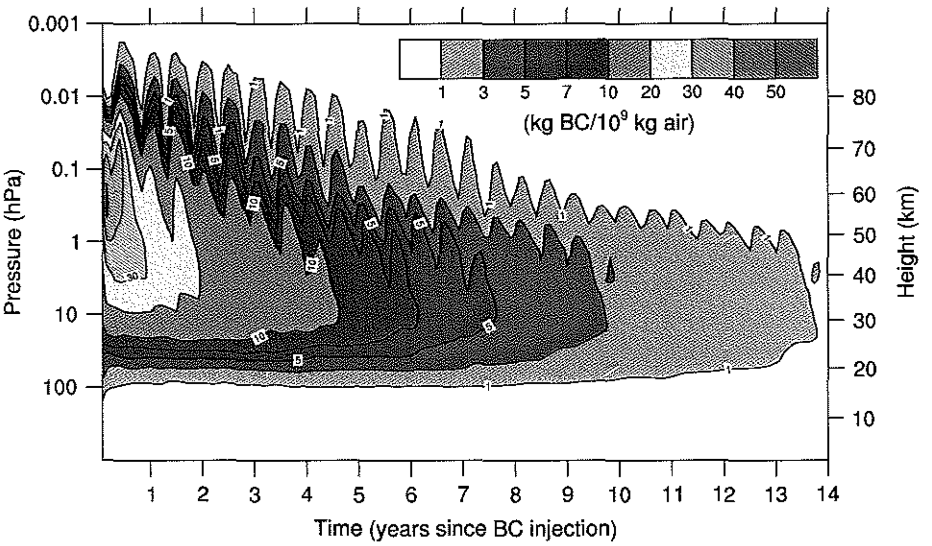

Figure 1. The time evolution of BC mass mixing ratio (kg BC/10^9 kg air) is shown for the average of the 50 nm experiment ensemble. The horizontal axis shows time in years since the emission of 5 Tg BC at 150–300 hPa on 1 January.

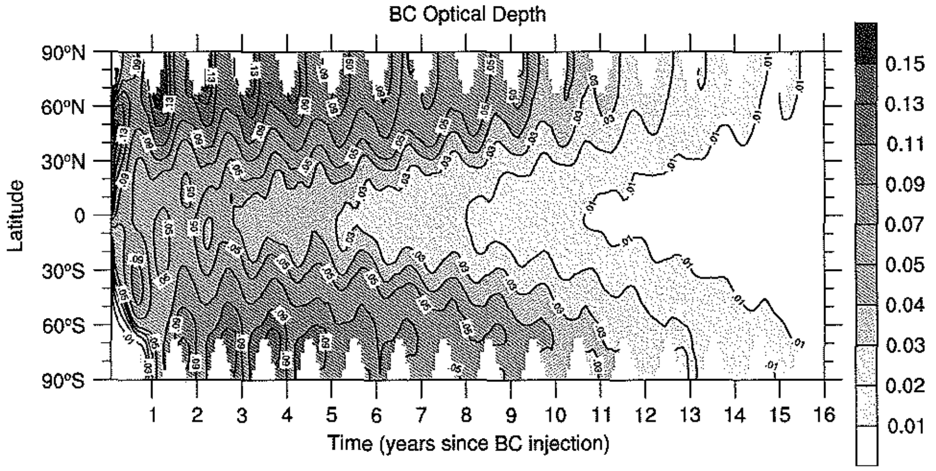

Figure 2. The time evolution of zonal mean total column BC optical depth in the visible part of the spectrum is shown for the 50 nm experiment ensemble average. The vertical axis shows latitude. The horizontal average shows time in years.

a similar assumption to the GISS ModelE. *Stenke et al.* [2013] calculate an initial rainout of ~2 Tg in their interactive 5 Tg simulations, which assumed BC radii of 50 and 100 nm in two separate runs. After initial rainout, the mass e-folding time for our remaining BC is 8.7 years for the average of our 50 nm experiment ensemble and 8.4 years for our 100 nm experiment, compared to the 6 years reported by *Robock et al.* [2007b], ~6.5 years by *Mills et al.* [2008], 4–4.6 years reported by *Stenke et al.* [2013], and 1 year for stratospheric sulfate aerosol from typical volcanic eruptions [*Oman et al.*, 2006]. Due to this longer lifetime, after about 4.8 years the global mass burden of BC we calculate in our ensemble is larger than that calculated by the GISS ModelE, despite the initial 28% rainout loss. After 10 years, we calculate that 1.1 Tg of BC remains in the atmosphere in our 50 nm experiment ensemble and 0.82 Tg in our 100 nm experiment, compared to 0.54 Tg calculated by the GISS ModelE and 0.07–0.14 Tg calculated by SOCOL3.

The long lifetime that we calculate results from both the very high initial lofting of BC to altitudes, where removal from the stratosphere is slow, and the subsequent slowing down of the stratospheric residual circulation. The Brewer-Dobson circulation is driven waves whose propagation is filtered by zonal winds,

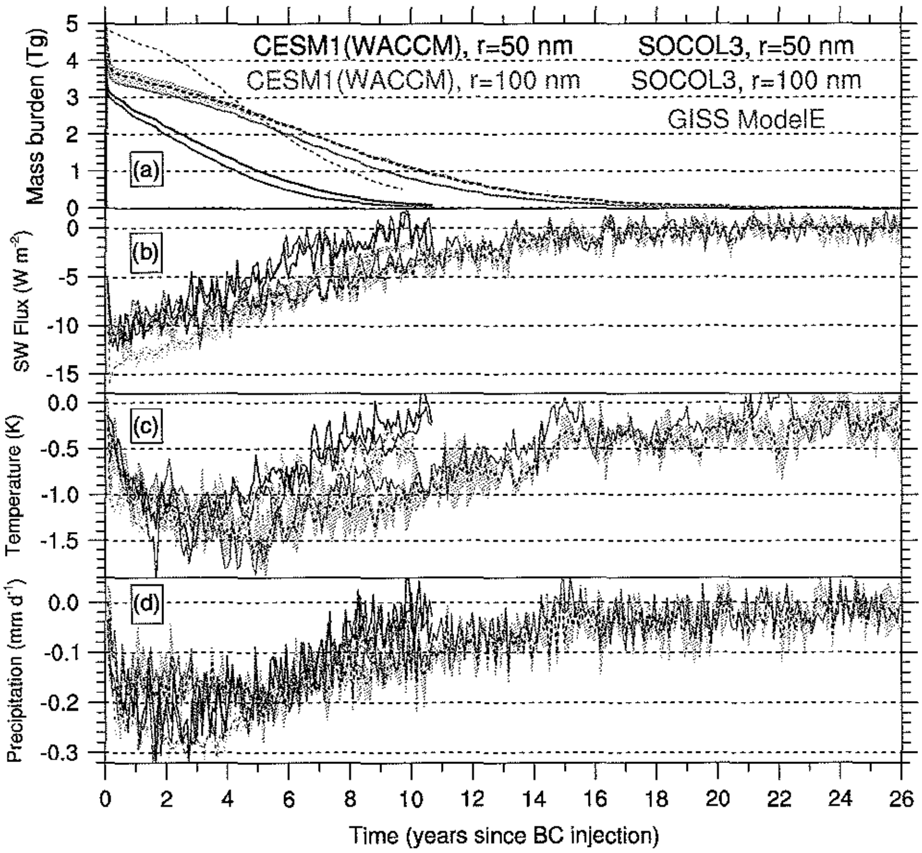

Figure 3. The monthly global mean time evolution is shown for (a) the mass burden of black carbon (Tg), (b) the shortwave net flux anomaly at the surface ($W\,m^{-2}$), (c) the surface temperature anomaly (K), and (d) the precipitation anomaly (mm/day). The dark blue dashed line and light blue shading show the average and range of our 50 nm experiment ensemble. The gold line shows our simulation assuming a 100 nm aerosol radius. The dark red dashed line and pink shading show the ensemble average and range for *Robock et al.* [2007a, 2007b] (data courtesy L. Oman). The grey and green lines show results from two 5 Tg BC simulations from *Stenke et al.* [2013] (data courtesy A. Stenke), with assumed aerosol radii of 50 and 100 nm, respectively. Ensemble anomalies are calculated with respect to the mean of the respective control simulation ensembles. Time 0 corresponds to the date of the BC injection (1 January in this study and 15 May in the other studies).

which are modulated by temperature gradients [*Garcia and Randel*, 2008]. As explained by *Mills et al.* [2008], the BC both heats the stratosphere and cools the surface, reducing the strength of the stratospheric overturning circulation. Figure 4 shows the vertical winds in the lower stratosphere, which bring new air up from the troposphere and drive the poleward circulation, for the control and BC runs. The middle-atmosphere heating and surface cooling reduce the average velocity of tropical updrafts by more than 50%. This effect persists more than twice as long as in *Mills et al.* [2008], which did not include any ocean cooling effects.

3.3. Global Mean Climate Anomalies

The global climate anomalies shown in Figure 3 respond very similarly in our 50 nm experiment ensemble and our 100 nm experiment; here we discuss the 50 nm calculations. The 3.6 Tg of BC that reaches the middle atmosphere and spreads globally absorbs the incoming SW solar radiation, reducing the net SW flux at the surface by ~12 W/m^2 initially or about 8% (Figure 3b). This anomaly tracks the evolution of the global mass burden of BC proportionally, similar to those calculated by GISS ModelE and SOCOL3. The SW flux in SOCOL3 seems to be more sensitive to BC than CESM1(WACCM), calculating comparable initial flux reductions with significantly lower BC burdens. In contrast, GISS ModelE and CESM1(WACCM) have similar sensitivity, producing very comparable flux anomalies in years 4 and 5, when the global mass burdens match most closely for the two models. After 10 years, our calculated SW flux anomaly persists at

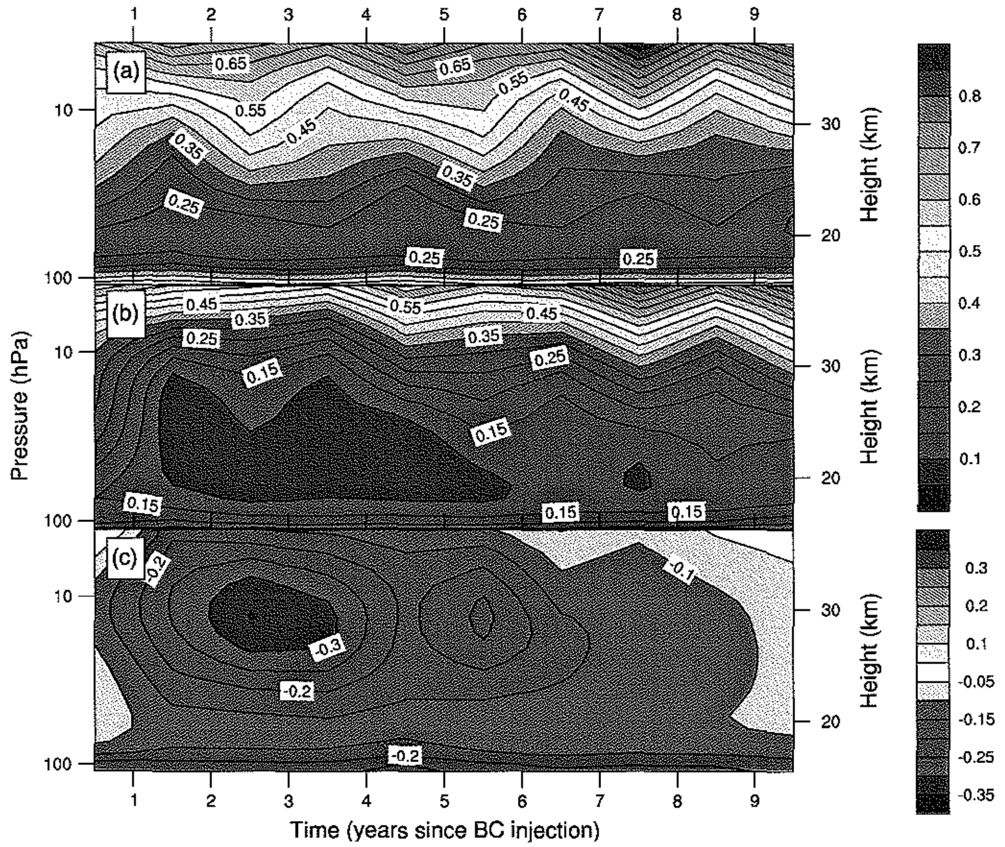

Figure 4. The time evolution of the tropical lower stratospheric vertical wind (mm/s) is shown for (a) the control, (b) the 50 nm experiment, and (c) and the experiment minus the control. Values are ensemble averages for latitudes 22°S to 22°N. The horizontal axis shows time in years. The left vertical axis shows pressure in hPa, and the right shows approximate pressure altitude in km.

−3.8 W/m^2, comparable to the maximum forcing of the 1991 Mount Pinatubo volcanic eruption [*Kirchner et al.*, 1999]. This is 2.7 times that of the flux anomaly calculated by GISS ModelE, with 2.0 times the mass burden. SOCOL3 fluxes have returned to normal after 10 years as BC mass burdens become insignificant. CESM1(WACCM) takes twice as long (20 years) to do the same.

Our calculated global average surface temperatures drop by ~1.1 K in the first year (Figure 3c). This response is initially slower than that calculated by the GISS ModelE, due to the large initial rainout, but comparable to SOCOL3. The initial temperature anomalies for the three models correspond proportionately to their initial SW anomalies. Our temperatures continue to decrease for 5 years, however, reaching a maximum cooling of 1.6 K in year 5, 2–2.5 years after GISS ModelE and SOCOL3 begin warming from their maximum cooling of comparable magnitude. After a decade, our calculated global average cooling persists at ~1.1 K, two to four times that calculated by GISS ModelE and SOCOL3. For CESM1(WACCM) and GISS Model E, this difference is roughly proportional with the ratio of mass burdens calculated. Our calculated cooling lags the recovery in mass burden and SW flux, however. Global average temperatures remain 0.25–0.50 K below the control ensemble average in years 20–23, after SW fluxes have returned to the control range. The thermal inertia of the oceans, which have experienced more than a decade of prolonged cooling, is responsible for much of this lag.

Precipitation rates drop globally by ~0.18 mm/day within the first year after the conflict. This 6% loss in the global average persists for 5 years, during which time our calculated response is not as strong as that calculated by either GISS ModelE or SOCOL3. The fairly constant precipitation anomaly that we calculate over the first 5 years is explained by the opposing trends in surface temperature and SW flux over this period, which tend to cancel each other out. In year 5, however, precipitation drops further as temperatures continue to fall, reaching a maximum reduction of 9% in global precipitation while precipitation in the other two models is in their second year of recovery. At the end of a decade, our calculated global precipitation is still reduced by 4.5%, and more than five times the reduction calculated at that time by GISS ModelE or SOCOL3. After 26 years, global average temperature and precipitation both remain slightly below the control ensemble average.

3.4. Ocean and Sea Ice Response

As Figure 5 shows, sea ice extent expands significantly over the first 5 years in the Arctic, and the first 10 years in the Antarctic. Sea ice extent is defined as the total area of all surface grid points in the ocean model with sea ice coverage greater than 15%. Both hemispheres experience an earlier onset of sea ice formation in the autumn, as revealed by the seasonal maxima, consistent with *Stenke et al.* [2013]. In the Arctic, sea ice extent increases peak at 10%–25% in years 4–7. Antarctic sea ice extent peaks at 20%–75% larger than the control ensemble in years 7–15, and remains 5%–10% larger throughout the years 20–26. These vast expansions of sea ice affect not only transfer of energy between the atmosphere and the oceans but also enhance planetary albedo, further cooling the surface by reflecting more sunlight to space. Expanding sea ice would also have large impacts on ocean life, strongly impacting the range of organisms that are in equilibrium with the current climate [e.g., *Harley et al.*, 2006].

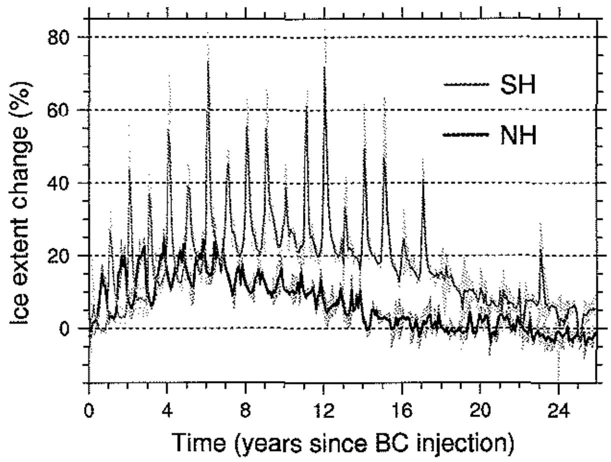

Figure 5. Change in sea ice extent (%) for the 50 nm experiment is shown relative to the control. Sea ice extent is defined as the area of all sea surface grid points with ice fraction greater than 15%. The red line shows the ensemble average anomaly for the Southern Hemisphere. The blue line shows the same for the Northern Hemisphere. Shading around each line shows the range of the experiment ensemble runs with respect to the control ensemble average. The horizontal axis shows time in years. The vertical axis shows relative change in ice extent area, 100% × (experiment − control)/control.

We also find that the upper layer of the ocean experiences a prolonged cooling that penetrates to hundreds of meters depth. Figure 6 shows the monthly global average ocean temperature anomalies at various depths for the 50 nm experiment ensemble, including ensemble variability, compared to the control ensemble average. As the figure shows, average cooling exceeding 0.5 K extends to 100 m depth through year 12. The upper 2.5 m of the ocean has the same heat capacity per unit area as the whole depth of the atmosphere [*Gill*, 1982]. Hence, this significant cooling down to 100 m depth creates a long-lived thermal deficit that maintains reduced surface temperature for decades. The temperature response takes longer to penetrate to deeper waters, with temperatures at 1000 m continuing to drop for all 26 years simulated.

3.5. Stratospheric Ozone Loss

The absorbing BC not only cools the surface but also severely heats the middle atmosphere (Figure 7). As in *Mills et al.* [2008], we calculate initial global average temperature increases in excess of 80 K near the stratopause (50–60 km). As in *Robock et al.* [2007b], we calculate global average stratospheric heating in excess of 30 K for the first 5 years. Figure 7 also reveals the surface cooling discussed above, as well as a cooling of the atmosphere above the BC layer, consistent with *Robock et al.* [2007b].

As in *Mills et al.* [2008], we calculate massive ozone loss as a consequence of these extreme stratospheric temperatures (Figure 8). Consistent with that work, we calculate a global average column ozone loss of 20%–25% persisting from the second through the fifth year after the nuclear war, and recovering to 8% column loss at the end of 10 years. Throughout the first 5 years, column ozone is reduced by 30%–40% at midlatitudes and by 50%–60% at northern high latitudes.

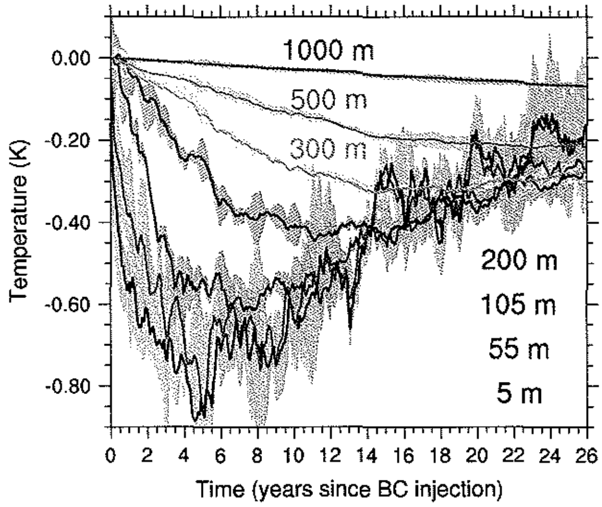

Figure 6. The time evolution of the global average ocean temperature anomaly at various depths is shown. The lines show the monthly average of the experiment ensemble temperatures minus the monthly average of the control ensemble. Shading around each line shows the range of the experiment ensemble runs with respect to the control ensemble average. The horizontal axis shows time in years. The vertical axis shows temperature in K.

As *Mills et al.* [2008] discussed, this ozone loss results primarily from two temperature-sensitive catalytic loss cycles involving odd oxygen and odd nitrogen, which accelerate at high temperatures. In addition, analysis of our current results shows that heating of the tropical tropopause allows up to 4.3 times as much water vapor to enter the lower stratosphere. The enhanced water vapor has a twofold effect on depleting ozone. Photolysis of water vapor produces both odd hydrogen and excited-state atomic oxygen, $O(^1D)$, depending on the wavelength of dissociating sunlight. $O(^1D)$ is responsible for the production of odd nitrogen in the stratosphere via reaction with N_2O. Odd hydrogen has its own catalytic cycle destroying ozone. We calculate that odd hydrogen in the tropical lower stratosphere is enhanced by factors of 3–5.5 over the first 2 years after the nuclear war. Similarly, $O(^1D)$ is enhanced in the same region by factors of 4–7.6. $O(^1D)$ is not the major loss mechanism for N_2O in the stratosphere, however, and N_2O levels are initially slightly elevated in the tropical stratosphere, likely due to uplift by the initial rise of the plume, as described by *Mills et al.* [2008]. Subsequent slowing of the stratospheric circulation produces reduced N_2O levels, as increased age of air results in increased chemical loss.

Ozone production rates are highest in the Tropics, where losses are dominated by transport of ozone to higher latitudes. As air is transported poleward, the chemical losses accumulate, leading to higher column losses at higher latitudes. At southern high latitudes, ozone losses are mitigated by the elimination

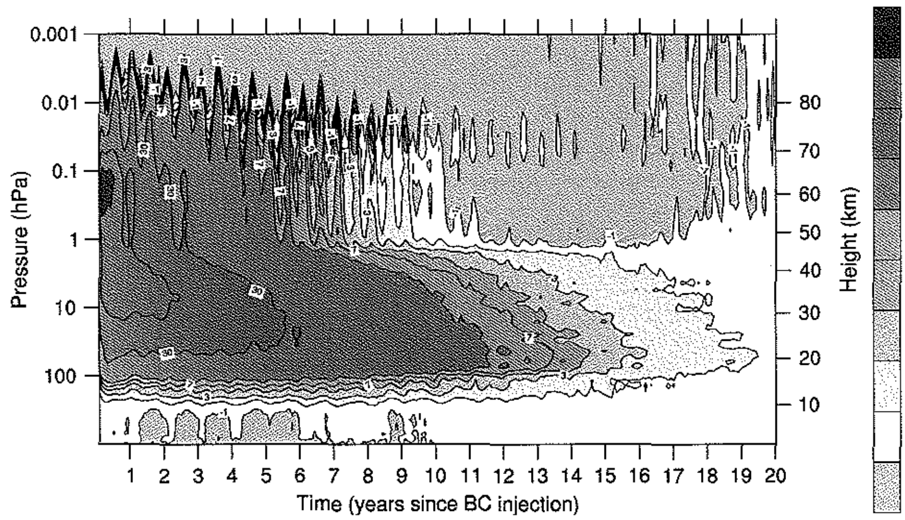

Figure 7. The time evolution of the vertical profile of global average temperature anomaly is shown. Values are for the 50 nm experiment ensemble average minus the control ensemble average. The horizontal axis shows time in years. The left vertical axis shows pressure in hPa, and the right vertical axis shows approximate pressure altitude in km. Contours show temperature anomalies in K.

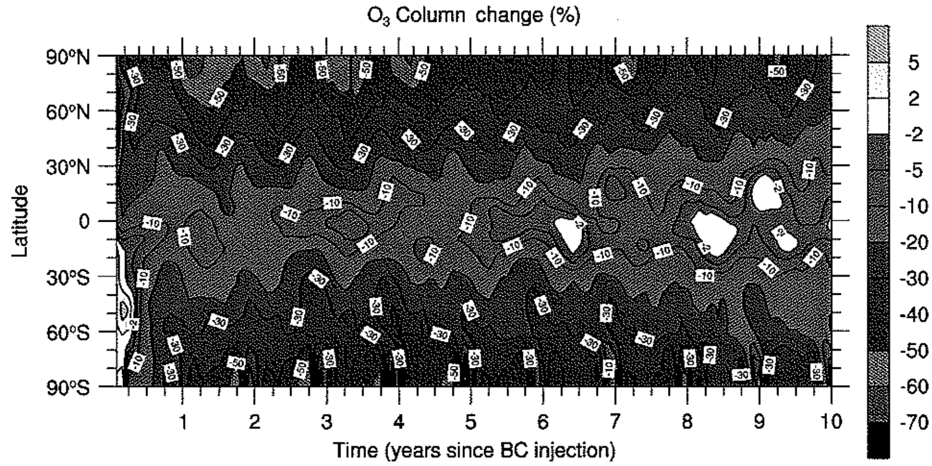

Figure 8. The time evolution of the change (%) in zonal mean column ozone is shown. The change in the 50 nm experiment ensemble average is shown relative to the control ensemble average: 100% × (experiment − control)/control. The horizontal axis shows time in years. The vertical axis shows latitude.

of the seasonal Antarctic ozone hole, which normally results from heterogeneous chemistry occurring on polar stratospheric clouds (PSCs) only at the extreme low temperatures present in the Antarctic stratosphere. We do not include effects of heterogeneous chemistry on BC aerosol, which is less understood than chemistry on sulfates and PSCs.

3.6. Changes in Surface UV Radiation

We used the TUV (tropospheric ultraviolet-visible) model [*Madronich and Flocke*, 1997] to calculate the impacts of this massive ozone loss on fluxes of damaging UV radiation reaching the Earth's surface. TUV simulates the attenuation of sunlight on its journey through Earth's atmosphere. The model has been used to study a wide range of topics including chemistry of the remote [*Walega et al.*, 1992] and urban atmosphere [*Castro et al.*, 2001], chemistry within snowpacks [*Fisher et al.*, 2005], incidence of skin cancer [*Thomas et al.*, 2007], methane emissions from plants [*Bloom et al.*, 2010], and potential changes to UV resulting from asteroid impacts [*Pierazzo et al.*, 2010] and geoengineering [*Tilmes et al.*, 2012]. The method used in this study is based on that described by *Lee-Taylor et al.* [2010].

We used TUV to calculate UV fluxes for clear sky conditions, based on the monthly average column ozone and absorbing BC distributions calculated for the control and experiment ensemble averages of our CESM1(WACCM) runs. To reduce computational overhead, we precalculated lookup tables of UV variation with respect to ozone, solar zenith angle (θ), and surface elevation, using the full 80 km atmospheric column considered by TUV. We then constructed global distributions of UV from the modeled WACCM ozone distributions using Beer's law to account for the slant-path absorption by the stratospheric BC, performing the calculation daily to account for varying θ. We express the monthly averaged UV results in terms of the international UV Index (UVI) [WHO, WMO, UNEP, and ICNIRP, 2002], which weights noontime UV fluxes by an "action spectrum" to account for the wavelength dependence of the effectiveness of solar radiation at causing skin damage [*McKinlay and Diffey*, 1987].

Figure 9 shows UVI in the peak summer months of June for the Northern Hemisphere and December for the Southern Hemisphere. The World Health Organization recommends that sun protection measures be taken for UV indices of 3 and above, and characterizes UVI values of 8–10 as "very high," warranting extra protection measures to avoid exposure to sunlight during midday hours. UVI greater than 11 is considered "extreme." We calculate UVI increases of 3–6 throughout the midlatitudes in summer, bringing peak values off the charts at 12–21 over the most populous regions of North America and southern Europe in June. We find similar increases for Australia, New Zealand, southern Africa, and South America in December. Skin damage varies with skin type, with burn times inversely proportional to UVI. Hence, a moderately fair-skinned North American who experiences a painful, noticeable sunburn after 10 min in the sun at noon in June for a UVI of 10 would receive an equivalent level of damage after 6.25 min for a UVI of 16.

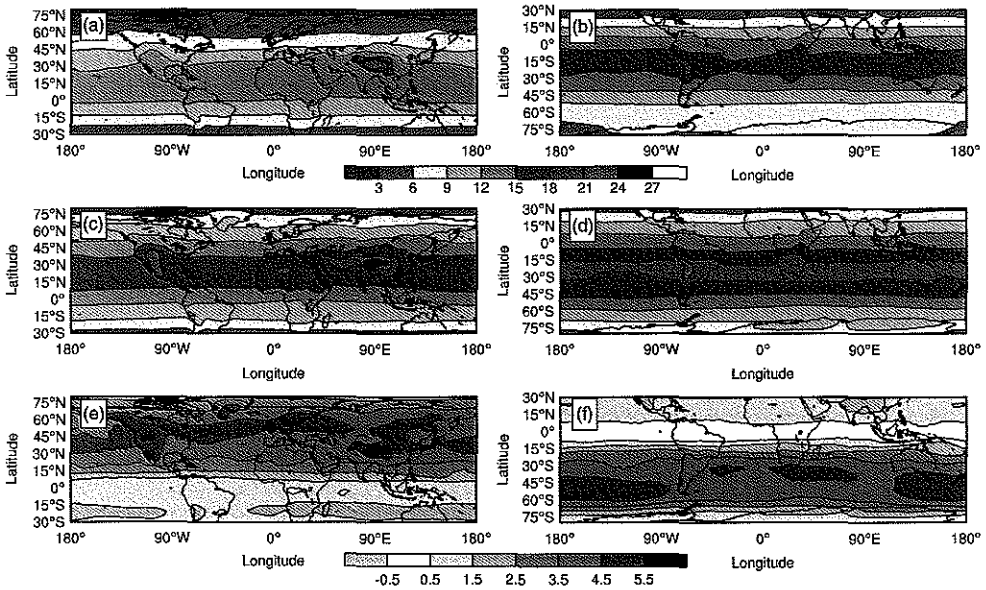

Figure 9. UV index in June (left) and December (right) is shown for the control (a, b), the experiment (c, d), and the experiment minus the control (e, f). Values are ensemble averages for year 3.

Stenke et al. [2013] calculate similarly dramatic increases in UV radiation due to ozone loss. They also report that the attenuation of solar fluxes from BC absorption was significant enough in high-latitude winter to reduce UV levels by 30% when they are most needed for vitamin D production. In contrast, we do not find that BC attenuation is significant enough to offset the UV increases from ozone loss.

The calculations shown in Figure 9 include absorption of UV by the BC, but not scattering, which presents an additional source of uncertainty. We performed a sensitivity test at 305 nm using a nominal single-scattering albedo of 0.31 for a 1 km depth soot layer centered on 27 km and a total ozone column of 200 DU. We calculate that BC scattering produces small reductions in ground-level UV irradiance, ranging from 4% for overhead sun and soot optical depth of 0.05 to 12% for θ of 88° and soot optical depth of 0.1. Hence, scattering would only marginally offset the 30%–100% increases in UV irradiance that we calculate for summer in the extratropics.

3.7. Effects on Vegetation and Agriculture

The severe increases in UV radiation following a regional nuclear war would occur in conjunction with the coldest average surface temperatures in the last 1000 years [*Mann et al.*, 1999]. Although global average surface temperatures would drop by 1.5 K (Figure 3c), broad, populated regions of continental landmasses would experience significantly larger cooling, as shown in Figure 10. Winters (JJA) in southern Africa and South America would be up to 2.5 K cooler on average for 5 years, compared to the same years (2–6) in the control run. Most of North America, Asia, Europe, and the Middle East would experience winters (DJF) that are 2.5–6 K cooler than the control ensemble, and summers (JJA) 1–4 K cooler.

Similarly, the 6% global average drop in precipitation that persists through years 2–6 (Figure 3d) translates into more significant regional drying (Figure 11). The most evident feature is over the Asian monsoon region, including the Middle East, the Indian subcontinent, and Southeast Asia. Broad precipitation reductions of 0.5–1.5 mm/day would reduce annual rainfall by 20%–80%. Similarly, large relative reductions in rainfall would occur in the Amazon region of South America, and southern Africa. The American Southwest and Western Australia would be 20%–60% drier. *Robock et al.* [2007b] predict a broadly wetter Sahel region as a result of a weaker Hadley circulation. *Stenke et al.* [2013] do not find such increased precipitation, and nor do we, despite some increase in precipitation near Morocco.

Following *Robock et al.* [2007b], we have calculated the change in the frost-free growing season, defined as the number of consecutive days in a 1 year period with minimum temperatures above 0°C (Figure 12).

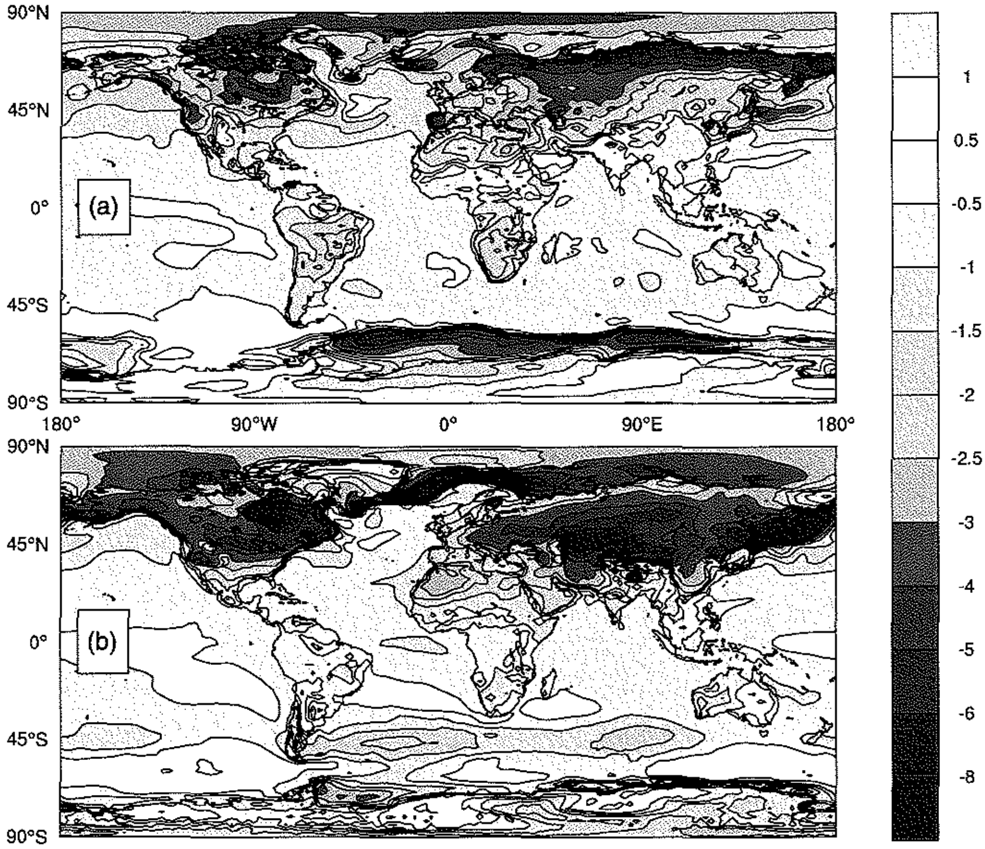

Figure 10. Change in surface temperature (K) for (a) June to August and (b) December to February. Values are 5 year seasonal ensemble averages for years 2–6, experiment minus control.

Because our globally averaged surface temperatures continue to cool until year 6, we show the average change in the growing season over years 2–6. The length of the average growing season is reduced by up to 40 days throughout the world's agricultural zones over these 5 years. This is similar to the results that *Robock et al.* [2007b] report for their first year, with significant regional differences. We find more significant decreases in Russia, North Africa, the Middle East, and the Himalayas than the previous study, and somewhat smaller effects in the American Midwest and South America.

The land component in CESM1(WACCM) is CLM4CN, a comprehensive land carbon cycle model [*Lawrence et al.*, 2011]. CLM4CN is prognostic with respect to carbon and nitrogen state variables in vegetation, litter, and soil organic matter. Vegetation carbon is affected by temperature, precipitation, solar radiation (and its partitioning into direct and diffuse radiation), humidity, soil moisture, and nitrogen availability, among other factors. We calculate an average loss of 11 Pg C from vegetation (2% of the total), which equates to an increase in atmospheric CO_2 of about 5 ppmv (5×10^{-6} molec/molec air). We also note a significant (42%–46%) increase in C loss from fires in the Amazon over the first 8 years in two of our three 50 nm experiment ensemble. The third run showed Amazon fire loss 13% higher than the control average, but within the variability of the control ensemble. Our runs do not account for the atmospheric effects of CO_2 or smoke emissions from the land component, but the smoke from the Amazon-kindled fires would be a positive feedback that would enhance the cooling we have found.

4. Discussion

Pierazzo et al. [2010] reviewed literature considering the effects of large and prolonged increases in UV-B radiation, similar to those we calculate, on living organisms, including agriculture and marine

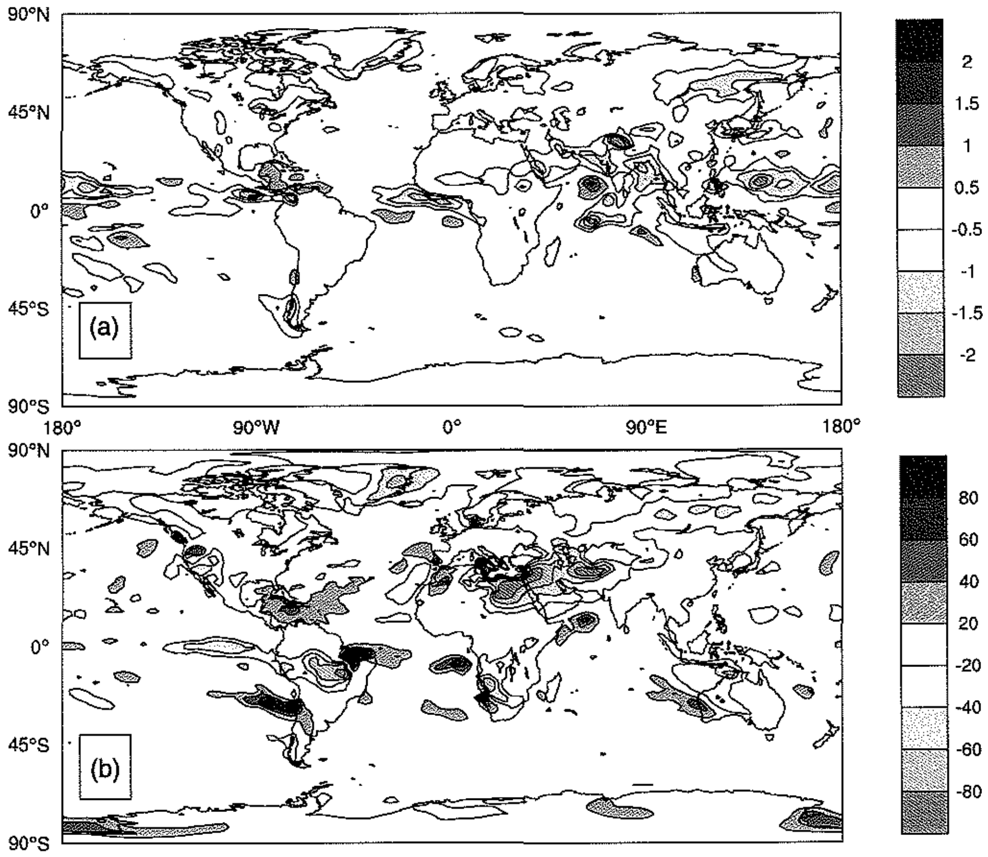

Figure 11. Changes in (a) absolute (mm/day) and (b) relative (%) surface precipitation. Values are 5 year seasonal ensemble averages for June to August, years 2–6, experiment minus control.

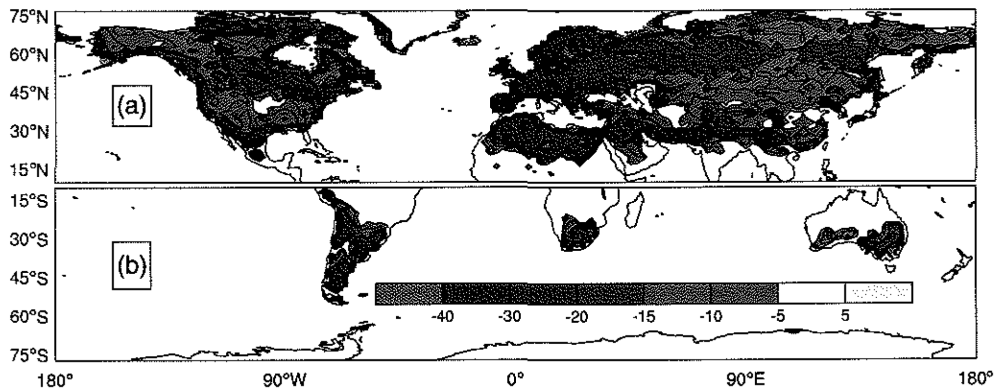

Figure 12. Change in frost-free growing season in days for (a) January to December in the Northern Hemisphere and (b) July to June in the Southern Hemisphere. Values are 5 year seasonal ensemble averages for years 2–6, experiment minus control.

ecosystems. General effects on terrestrial plants have been found to include reduced height, shoot mass, and foliage area [*Caldwell et al.*, 2007]. *Walbot* [1999] found the DNA damage to maize crops from 33% ozone depletion to accumulate proportionally to exposure time, being passed to successive generations, and destabilizing genetic lines. Research indicates that UV-B exposure may alter the susceptibility of plants to attack by insects, alter nutrient cycling in soils (including nitrogen fixation by cyanobacteria), and shift competitive balances among species [*Caldwell et al.*, 1998; *Solheim et al.*, 2002; *Mpoloka*, 2008].

The ozone depletion we calculate could also damage aquatic ecosystems, which supply more than 30% of the animal protein consumed by humans. *Häder et al.* [1995] estimate that 16% ozone depletion could reduce phytoplankton, the basis of the marine food chain, by 5%, resulting in a loss of 7 million tons of fish harvest per year. They also report that elevated UV levels damage the early developmental stages of fish, shrimp, crab, amphibians, and other animals. The combined effects of elevated UV levels alone on terrestrial agriculture and marine ecosystems could put significant pressures on global food security.

The ozone loss would persist for a decade at the same time that growing seasons would be reduced by killing frosts, and regional precipitation patterns would shift. The combination of years of killing frosts, reductions in needed precipitation, and prolonged enhancement of UV radiation, in addition to impacts on fisheries because of temperature and salinity changes, could exert significant pressures on food supplies across many regions of the globe. As the January to May 2008 global rice crisis demonstrated, even relatively small food price pressures can be amplified by political reactions, such as the fearful restrictions on food exports implemented by India and Vietnam, followed by Egypt, Pakistan, and Brazil, which produced severe shortages in the Philippines, Africa, and Latin America [Slayton, 2009]. It is conceivable that the global pressures on food supplies from a regional nuclear conflict could, directly or via ensuing panic, significantly degrade global food security or even produce a global nuclear famine.

5. Summary

We present the first simulations of the chemistry-climate effects of smoke produced by a nuclear war using an Earth system model that includes both stratospheric chemistry and feedbacks on sea ice and deep ocean circulation. We calculate impacts on surface climate persisting significantly longer than previous studies, as a result of several feedback mechanisms. First, BC absorbs sunlight, heating ambient air, and self-lofts to the upper stratosphere, a region treated with greater vertical resolution in CESM1(WACCM) than in the model used by *Robock et al.* [2007b]. Second, the BC spreads globally, absorbing sunlight, which heats the stratosphere and cools the surface. This has the effect of reducing the strength of the stratospheric circulation and increasing the lifetime of BC in the stratosphere. Third, the reduction of surface temperatures cools the upper 100 m of the ocean by >0.5 K for 12 years, and expands ice extent on sea and land. This lends inertia to the surface cooling due to both thermal mass and enhanced albedo, causing recovery in surface temperatures to lag the recovery in BC by a decade or more. As a result, we calculate that surface temperatures remain below the control ensemble range even 26 years after the nuclear war.

The global average temperature increase in the stratosphere following the BC injection initially exceeds 70 K, and persists above 30 K for 5 years, with full recovery taking two decades. As in previous studies, this temperature increase produces global ozone loss on a scale never observed, as a result of several chemical mechanisms. The resulting enhancements to UV radiation at the surface would be directly damaging to human health, and would damage agricultural crops, as well as ecosystems on land and in the oceans.

These results illustrate some of the severe negative consequences of the use of only 100 of the smallest nuclear weapons in modern megacities. Yet the United States, Russia, the United Kingdom, China, and France each have stockpiles of much larger nuclear weapons that dwarf the 100 examined here [*Robock et al.*, 2007a; *Toon et al.*, 2007]. Knowing the perils to human society and other forms of life on Earth of even small numbers of nuclear weapons, societies can better understand the urgent need to eliminate this danger worldwide.

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References

Bloom, A. A., J. Lee-Taylor, S. Madronich, D. J. Messenger, P. I. Palmer, D. S. Reay, and A. R. McLeod (2010), Global methane emission estimates from ultraviolet irradiation of terrestrial plant foliage, *New Phytol.*, *187*(2), 417–425, doi:10.1111/j.1469-8137.2010.03259.x.
Caldwell, M. M., L. O. Björn, J. F. Bornman, S. D. Flint, G. Kulandaivelu, A. H. Teramura, and M. Tevini (1998), Effects of increased solar ultraviolet radiation on terrestrial ecosystems, *J. Photochem. Photobiol. B: Biol.*, *46*(1), 40–52.
Caldwell, M. M., J. F. Bornman, C. L. Ballaré, S. D. Flint, and G. Kulandaivelu (2007), Terrestrial ecosystems, increased solar ultraviolet radiation, and interactions with other climate change factors, *Photochem. Photobiol. Sci.*, *6*(3), 252–266, doi:10.1039/b700019g.
Castro, T., S. Madronich, S. Rivale, A. Muhlia, and B. Mar (2001), The influence of aerosols on photochemical smog in Mexico City, *Atmos. Environ.*, *35*(10), 1765–1772, doi:10.1016/S1352-2310(00)00449-0.
Crutzen, P., and J. Birks (1982), Twilight at noon: The atmosphere after a nuclear war, *Ambio*, *11*, 114–125.
Danabasoglu, G., S. C. Bates, B. P. Briegleb, S. R. Jayne, M. Jochum, W. G. Large, S. Peacock, and S. G. Yeager (2012), The CCSM4 ocean component, *J. Clim.*, *25*(5), 1361–1389, doi:10.1175/JCLI-D-11-00091.1.

Fisher, F. N., M. D. King, and J. Lee-Taylor (2005), Extinction of UV-visible radiation in wet midlatitude (maritime) snow: Implications for increased NOx emission, *J. Geophys. Res.*, *110*(D21), D21301, doi:10.1029/2005JD005963.

Garcia, R. R., and W. J. Randel (2008), Acceleration of the Brewer-Dobson circulation due to increases in greenhouse gases, *J. Atmos. Sci.*, *65*(8), 2731–2739, doi:10.1175/2008JAS2712.1.

Gill, A. (1982), *Atmosphere-Ocean Dynamics*, Academic Press, San Diego, Calif.

Häder, D. P., R. C. Worrest, and H. D. Kumar (1995), Effects of increased solar ultraviolet radiation on aquatic ecosystems, *Ambio*, *24*, 174–180.

Harley, C. D. G., A. Randall Hughes, K. M. Hultgren, B. G. Miner, C. J. Sorte, C. S. Thornber, L. F. Rodriguez, L. Tomanek, and S. L. Williams (2006), The impacts of climate change in coastal marine systems, *Ecol. Lett.*, *9*, 228–241, doi:10.1111/j.1461-0248.2005.00871.x.

Hess, M., P. Koepke, and I. Schult (1998), Optical properties of aerosols and clouds: The software package OPAC, *Bull. Am. Meteorol. Soc.*, *79*, 831, doi:10.1175/1520-0477(1998)079<0831:OPOAAC>2.0.CO;2.

Holland, M. M., D. A. Bailey, B. P. Briegleb, B. Light, and E. Hunke (2012), Improved sea ice shortwave radiation physics in CCSM4: The impact of melt ponds and aerosols on Arctic sea ice, *J. Clim.*, *25*(5), 1413–1430, doi:10.1175/JCLI-D-11-00078.1.

Hurrell, J. W., et al. (2013), The community earth system model: A framework for collaborative research, *Bull. Am. Meteorol. Soc.*, *94*, 1339–1360, doi:10.1175/BAMS-D-12-00121.1.

Kinnison, D. E., et al. (2007), Sensitivity of chemical tracers to meteorological parameters in the MOZART-3 chemical transport model, *J. Geophys. Res.*, *112*, 20,302, doi:10.1029/2006JD007879.

Kirchner, I., G. L. Stenchikov, H.-F. Graf, A. Robock, and J. C. Antuña (1999), Climate model simulation of winter warming and summer cooling following the 1991 Mount Pinatubo volcanic eruption, *J. Geophys. Res.*, *104*(D), 19,039–19,056, doi:10.1029/1999JD900213.

Lawrence, D. M., et al. (2011), Parameterization improvements and functional and structural advances in Version 4 of the Community Land Model, *J. Adv. Model. Earth Syst.*, *3*(3), 45, doi:10.1029/2011MS000045.

Lee-Taylor, J., S. Madronich, B. Mayer, and C. Fischer (2010), A climatology of UV radiation, 1979–2000, 65S - 65N, in *UV Radiation in Global Climate Change: Measurements, Modeling and Effects on Ecosystems*, edited by W. Gao, D. Schmoldt, and J. Slusser, pp. 2–20, Springer, Heidelberg, Germany.

Madronich, S., and S. Flocke (1997), Theoretical estimation of biologically effective UV radiation at the Earth's surface, in *Solar Ultraviolet Radiation—Modeling, Measurements and Effects, NATO ASI Ser.*, vol. I52, edited by C. Zerefos, pp. 23–48, Springer, Berlin, Germany.

Mann, M. E., R. S. Bradley, and M. K. Hughes (1999), Northern hemisphere temperatures during the past millennium: Inferences, uncertainties, and limitations, *Geophys. Res. Lett.*, *26*(6), 759–762, doi:10.1029/1999GL900070.

Marsh, D. R., M. J. Mills, D. E. Kinnison, J.-F. Lamarque, N. Calvo, and L. M. Polvani (2013), Climate change from 1850 to 2005 simulated in CESM1(WACCM), *J. Clim.*, *26*, 7372–7390, doi:10.1175/JCLI-D-12-00558.1.

McKinlay, F. A., and B. L. Diffey (1987), A reference action spectrum for ultraviolet induced erythema in human skin, in *Human Exposure to Ultraviolet Radiation*, edited by F. W. Passchier and B. Bosnjakovic, pp. 83–87, Elsevier, Amsterdam, Netherlands.

Meinshausen, M., et al. (2011), The RCP greenhouse gas concentrations and their extensions from 1765 to 2300, *Clim. Change*, *109*(1–2), 213–241, doi:10.1007/s10584-011-0156-z.

Mills, M. J., O. B. Toon, R. P. Turco, D. E. Kinnison, and R. R. Garcia (2008), Massive global ozone loss predicted following regional nuclear conflict, *Proc. Natl. Acad. Sci. U.S.A.*, *105*, 5307–5312, doi:10.1073/pnas.0710058105.

Mpoloka, S. W. (2008), Effects of prolonged UV-B exposure in plants, *Afr. J. Biotechnol.*, *7*(25), 4874–4883, http://www.ajol.info/index.php/ajb/article/viewFile/59692/47971.

National Research Council (1985), *The Effects on the Atmosphere of a Major Nuclear Exchange*, National Academy Press, Washington, D. C.

Neale, R. B., J. H. Richter, S. Park, P. H. Lauritzen, S. J. Vavrus, P. J. Rasch, and M. Zhang (2013), The mean climate of the community atmosphere model (CAM4) in forced SST and fully coupled experiments, *J. Clim.*, *26*, 5150–5168, doi:10.1175/JCLI-D-12-00236.1.

Oman, L., A. Robock, G. L. Stenchikov, T. Thordarson, D. Koch, D. T. Shindell, and C. Gao (2006), Modeling the distribution of the volcanic aerosol cloud from the 1783–1784 Laki eruption, *J. Geophys. Res.*, *111*, D12209, doi:10.1029/2005JD006899.

Pierazzo, E., R. R. Garcia, D. E. Kinnison, D. R. Marsh, and P. J. Crutzen (2010), Ozone perturbation from medium-size asteroid impacts in the ocean, *Earth Planet. Sci. Lett.*, *299*, 263–272, doi:10.1016/j.epsl.2010.08.036.

Pittock, A. B., T. Ackerman, P. Crutzen, M. MacCracken, C. Shapiro, and R. Turco (1985), *The Environmental Consequences of Nuclear War, vol. 1, Physical and Atmospheric Effects, SCOPE*, vol. 28, pp. 359, John Wiley, Chichester, U. K.

Robock, A., L. Oman, and G. L. Stenchikov (2007a), Nuclear winter revisited with a modern climate model and current nuclear arsenals: Still catastrophic consequences, *J. Geophys. Res.*, *112*, D13107, doi:10.1029/2006JD008235.

Robock, A., L. Oman, G. L. Stenchikov, O. B. Toon, C. G. Bardeen, and R. P. Turco (2007b), Climatic consequences of regional nuclear conflicts, *Atmos. Chem. Phys.*, *7*, 2003–2012, doi:10.5194/acp-7-2003-2007.

Ross, M., M. J. Mills, and D. Toohey (2010), Potential climate impact of black carbon emitted by rockets, *Geophys. Res. Lett.*, *37*(24), L24810, doi:10.1029/2010GL044548.

Slayton, T. (2009), Rice crisis forensics: How Asian governments carelessly set the world rice market on fire, Center for Global Development Working Paper No. 163., http://www.cgdev.org/sites/default/files/1421260_file_Slayton_Rice_Crisis_Forensics_FINAL.pdf.

Solheim, B., U. Johanson, T. Callaghan, J. Lee, D. Gwynn-Jones, and L. Björn (2002), The nitrogen fixation potential of arctic cryptogram species is influenced by enhanced UV-B radiation, *Oecologia*, *133*(1), 90–93, doi:10.1007/s00442-002-0963-z.

Stenke, A., C. R. Hoyle, B. Luo, E. Rozanov, J. Gröbner, L. Maag, S. Brönnimann, and T. Peter (2013), Climate and chemistry effects of a regional scale nuclear conflict, *Atmos. Chem. Phys.*, *13*, 9713–9729, doi:10.5194/acp-13-9713-2013.

Stephens, S., and J. Birks (1985), After nuclear war: Perturbations in atmospheric chemistry, *BioScience*, *35*(9), 557–562.

Thomas, N. E., et al. (2007), Number of nevi and early-life ambient UV exposure are associated with BRAF-mutant melanoma, *Cancer Epidemiol. Biomarkers Prev.*, *16*(5), 991–997, doi:10.1158/1055-9965.EPI-06-1038.

Tilmes, S., D. E. Kinnison, R. R. Garcia, R. Salawitch, T. Canty, J. Lee-Taylor, S. Madronich, and K. Chance (2012), Impact of very short-lived halogens on stratospheric ozone abundance and UV radiation in a geo-engineered atmosphere, *Atmos. Chem. Phys.*, *12*(2), 10,945–10,955, doi:10.5194/acp-12-10945-2012.

Toon, O. B., R. P. Turco, P. Hamill, C. S. Kiang, and R. C. Whitten (1979), A one-dimensional model describing aerosol formation and evolution in the stratosphere: II. Sensitivity studies and comparison with observations, *J. Atmos. Sci.*, *36*, 718–736, doi:10.1175/1520-0469(1979)036<0718:AODMDA>2.0.CO;2.

Toon, O. B., R. P. Turco, D. Westphal, R. Malone, and M. S. Liu (1988), A multidimensional model for aerosols: Description of computational analogs, *J. Atmos. Sci.*, *45*, 2123–2143, doi:10.1175/1520-0469(1988)0452.0.CO;2.

Toon, O. B., R. P. Turco, A. Robock, C. G. Bardeen, L. Oman, and G. L. Stenchikov (2007), Atmospheric effects and societal consequences of regional scale nuclear conflicts and acts of individual nuclear terrorism, *Atmos. Chem. Phys.*, *7*, 1973–2002, doi:10.5194/acp-7-1973-2007.

Toon, O. B., A. Robock, and R. P. Turco (2008), Environmental consequences of nuclear war, *Phys. Today*, *61*(12), 37–42, doi:10.1063/1.3047679.

Turco, R. P., P. Hamill, O. B. Toon, R. C. Whitten, and C. S. Kiang (1979), A one-dimensional model describing aerosol formation and evolution in the stratosphere: I. Physical processes and mathematical analogs, *J. Atmos. Sci.*, *36*, 699, doi:10.1175/1520-0469(1979)0362.0.CO;2.

Turco, R. P., O. B. Toon, T. P. Ackerman, J. B. Pollack, and C. Sagan (1983), Nuclear winter: Global consequences of multiple nuclear explosions, *Science*, *222*(4), 1283–1292, doi:10.1126/science.222.4630.1283.

Walbot, V. V. (1999), UV-B damage amplified by transposons in maize, *Nature*, *397*(6718), 398–399, doi:10.1038/17043.

Walega, J. G., B. A. Ridley, S. Madronich, F. E. Grahek, J. D. Shetter, T. D. Sauvain, C. J. Hahn, J. T. Merill, B. A. Bodhaine, and E. Robinson (1992), Observations of peroxyacetyl nitrate, peroxypropionyl nitrate, methyl nitrate and ozone during the Mauna Loa Observatory Photochemistry Experiment, *J. Geophys. Res.*, *97*, 10,311, doi:10.1029/91JD02288.

WHO, WMO, UNEP, and ICNIRP (2002), *Global Solar UV Index: A Practical Guide*, WHO, Geneva, Switzerland.

ANNEX 10 – House of Commons Defence Committee, 'The Future of the UK's Nuclear Deterrent: the White Paper' (HC 225-1), Vol. 1, ch. 2

2 The UK's nuclear deterrent

Table 1: The components of the UK's current nuclear deterrent

Platform	4 Vanguard-class nuclear-powered ballistic missile submarines, built in the UK
Missile	Each submarine is capable of carrying up to 16 Trident D5 submarine-launched intercontinental ballistic missiles, sourced from the US
Warhead	Each missile is capable of carrying 12 nuclear warheads, manufactured in the UK, but since 1998 the number of warheads per missile was has been limited to 3 warheads, and 48 warheads in total per submarine
Shore infrastructure	The Vanguard submarines are based at HM Naval Base Clyde at Faslane Nuclear warheads are fitted to the missiles at the Royal Naval Armaments Depot Coulport (part of HM Naval Base Clyde)
Warhead production and maintenance	The nuclear warheads are manufactured by the Atomic Weapons Establishment at Aldermaston and Burghfield, in Berkshire
Industrial base	The Vanguard submarines were designed and built by BAE Systems Submarines at Barrow-in-Furness, in Cumbria Refit and maintenance is carried out by Devonport Management Limited at Devonport in Plymouth The submarines' Nuclear Steam Raising Plants, including the nuclear reactors, are built by Rolls-Royce at Raynesway in Derbyshire There is an extensive supply chain

Components of the UK's nuclear deterrent

8. The UK's strategic nuclear deterrent is based upon the Trident weapons system. It is the UK's third-generation nuclear deterrent. It was developed during the final decade of the Cold War, and was introduced into service over a six-year period beginning in December 1994. It is the UK's sole nuclear weapons system: the UK disposed of its land-based Lance system, and air-launched WE 177 free-fall nuclear bombs in the 1990s.

9. The deterrent has three technical components:

- the Vanguard-class nuclear-powered ballistic missile submarine (SSBN), of which the UK has four, HMS *Vanguard*, *Victorious*, *Vigilant* and *Vengeance*, designed and built in the UK by Vickers Shipbuilding and Engineering Ltd. (VSEL), now BAE Systems, in Barrow-in-Furness, Cumbria.

- the Trident D5 submarine-launched intercontinental ballistic missile, manufactured in the USA by Lockheed Martin. Under the Polaris Sales Agreement (modified for Trident), the UK has title to 58 missiles, of which it has now used 8 in tests. Aside from those currently deployed, the missiles are held in a communal pool at the US Strategic Weapons facility at King's Bay, Georgia, USA.
- the nuclear warhead, designed and manufactured in the UK at the Atomic Weapons Establishment, Aldermaston and Burghfield in Berkshire. Each missile is capable of carrying 12 warheads, but since the 1998 Strategic Defence Review, the number of warheads per missile has been limited to 3 warheads (and 48 warheads in total per submarine).

10. The submarine fleet is supported by an extensive onshore infrastructure. This is described in detail in our second report.[6]

Operating posture of the UK's nuclear deterrent

11. The 1998 *Strategic Defence Review* (SDR) stated that the UK would continue to maintain continuous-at-sea deterrent (CASD) patrols. This meant that one of the UK's four Vanguard-class submarines would be on patrol at any give time. The SDR stated that the purpose of CASD was "to avoid misunderstanding or escalation if a Trident submarine were to sail during a period of crisis".[7] By keeping one submarine on patrol at all times, the UK avoids the risk of sending incorrect or misleading signals to a potential adversary at times of heightened alert. In our first report on the future of the UK's strategic nuclear deterrent, we suggested that if the MoD believed the UK should retain the continuous-at-sea deterrent cycle, it must either extend the life of the Vanguard-class submarine or procure a new platform to be in service by around 2020. The issue of maintaining continuous-at-sea deterrence is at the heart of the debate over the timing of decisions on the future of the UK's nuclear deterrent.

12. According to the MoD, a four boat fleet is normally required to guarantee one boat on patrol at all times, because one boat is either preparing to enter refit, in refit, or leaving refit and preparing to re-enter service, one is in maintenance between patrols, and one is either on its way to take up patrol or returning from patrol. By the time *Vanguard* goes out-of-service the last refit will have been completed, and so it will only be when *Victorious* goes out-of-service in 2024 that the MoD says the continuous-at-sea regime could not be sustained.

6 HC (2006–07) 59, paras 12–21

7 Cm 3999, p 19

ANNEX 11 – House of Commons Defence Committee, Session 2005-06, Eighth Report, para. 21
http://www.publications.parliament.uk/pa/cm200506/cmselect/cmdfence/986/986.pdf

targetable re-entry vehicle) capability which enables each Trident missile to engage multiple targets simultaneously.[19]

21. The Trident II D5 missile was designed and manufactured in the United States by Lockheed Martin. Under the Polaris Sales Agreement (modified for Trident), the UK has title to 58 missiles. Aside from those currently deployed, the missiles are held in a communal pool at the US Strategic Weapons facility at King's Bay, Georgia, USA. Maintenance and in-service support of the missiles is undertaken at periodic intervals at King's Bay, normally after a submarine has been through refit.[20]

The warhead

22. The nuclear warhead fitted to the tip of the Trident II D5 missile was designed and manufactured in the UK at the Atomic Weapons Establishment at Aldermaston, Berkshire. Although public information is limited, the nuclear warhead on UK's Trident II D5 missile is reported to be closely related to the American W76 warhead, a thermonuclear warhead with a yield of around 100 kilotons.[21]

23. During our visit to the United States in May 2006, we heard that the US and UK collaborated closely on nuclear weapons and that there was a rich flow of nuclear ideas between the US and the UK. We were also told that the fiftieth anniversary of the 1958 Mutual Defence Agreement, which formalised this cooperation, would be a cause for both pride and celebration.

Onshore infrastructure and skills base

24. The UK's Trident system is underpinned by a range of supporting industrial and manufacturing infrastructure.

25. **The submarine basing infrastructure:** The Naval Base at Faslane, Strathclyde, is home to the UK's Trident submarine force. It has a staff of over 7,000 and is also home to conventionally-armed submarines. The nuclear warheads carried onboard the Vanguard-class SSBN submarines are stored and fitted to the UK's Trident II D5 missiles at the Royal Naval Armaments Depot at Coulport, near Faslane.

26. **The onshore submarine construction and maintenance infrastructure:** This comprises the building yard at Barrow-in-Furness, Cumbria, owned by BAE Systems, and the operational and refit and support site at Devonport, Plymouth, owed by DML (a consortium of which fifty-one per cent is owned by the US firm Halliburton). This part of the defence industrial base is characterised by its need for a highly specialised and skilled workforce and large-scale purpose-built physical infrastructure. Together, these requirements are present at all stages of the nuclear-powered submarine's life, from concept design through to operation, maintenance and disposal and carry significant levels

19 Stockholm International Peace Research Institute, *SIPRI Yearbook 2005*, (Oxford 2005) p 589

20 *Ibid.*

21 Michael Clarke, "Does my Bomb look big in this?", *International Affairs*, vol 80, no. 1, (2004) p 37

ANNEX 12 – J. Ainslie, "United Kingdom" in *Assuring Destruction Forever: Nuclear Weapon Modernization Around the World*, Reaching Critical Will, 2012, p. 68. Available online at http://www.reachingcriticalwill.org/images/documents/Publications/modernization/assuring-destruction-forever.pdf

Fissile materials

When the UK government decided to acquire the Trident system, it calculated that it would need significant additional stocks of plutonium and highly enriched uranium (HEU).[15] Plutonium was produced in the UK.[16] HEU was procured from the United States.[17]

An analysis of published movements of plutonium through AWE suggests that Calder Hall and Chapelcross power stations produced over 1 tonne of weapon-grade plutonium for the Trident programme between 1985 and 1995.[18] The stockpile of military plutonium rose to 3.5 tonnes by 1995, when the UK ceased production of fissile materials. In 1999 the MoD placed 0.3 tonnes of weapon-grade plutonium under international safeguards, leaving 3.2 tonnes which are not subject to these safeguards safeguards.[19] The UK would appear to hold a substantial reserve of military plutonium, which is not subject to international safeguards, in addition to the material in warheads.[20]

IN DECEMBER 2006 PRESIDENT BUSH WROTE TO PRIME MINISTER BLAIR, AGREEING TO SUPPORT THE BRITISH NUCLEAR WEAPON PROGRAMME.

In 2006 the UK government published a report on the historical accounting of HEU.[21] This report is short on detail.[22] It says that the total amount of HEU which the UK had acquired by 2002 was 26.36 tonnes. 4.72 tonnes of this had been removed, leaving a balance of 21.64 tonnes.[23] The UK produced between 4 and 5 tonnes of HEU at Capenhurst between 1954 and 1962.[24] This implies that the UK procured an additional 21-22 tonnes of HEU from the US between 1964 and 2002.[25]

The report does not say what form this material takes. Large quantities of HEU were acquired for the naval nuclear propulsion programme. Some of the stock will be in the form of fuel on submarines. A significant amount may be in used fuel cores which have been removed from submarines and stored at Sellafield.[26] The size of the stocks held for future warheads and new fuel cores is not known.

The UK's nuclear-powered submarine programme creates an ongoing demand for weapons-grade HEU.[27] This may be met by placing new orders with the United States. The UK government is considering options for the acquisition of HEU for its Trident replacement programme.

Infrastructure

Nuclear warheads are developed and manufactured at the AWE sites of Aldermaston and Burghfield in Berkshire. The work at Aldermaston includes the production of plutonium, HEU, and Berylium components and research into warhead design. Warheads are assembled and disassembled at Burghfield.

Vangiard class submarines operate from Faslane and nuclear warheads are stored at Coulport. Both sites are parts of HM Clyde Naval Base in Scotland.

Submarines are built at Barrow in Furness. The fuel cores for naval reactors are manufactured by Rolls Royce in Derby. There is normally one Vanguard class submarine in refit at Devonport dockyard. Rolls Royce operates a prototype submarine reactor at HMS Vulcan, Dounreay. It is planning to close down this reactor in 2015 but to keep on the workforce until 2030.[28]

The nuclear firing chain is a "substantial element" of the overall infrastructure which supports Trident.[29] It includes Command, Control, Communications, and Computers (C4). There are three key facilities: the Nuclear Operations and Targeting Centre, underneath the MoD Main Building in Whitehall, London; Commander Task Force (CTF) 345, at the Permanent Joint Headquarters, Northwood, Middlesex; and Corsham Computer Centre, a deep underground bunker in Wiltshire that processes the UK's fire control and targeting software. Launch instructions would be issued over all available frequencies from the Defence Communications hub, which is also at Corsham. The primary means of maintaining radio contact with submarines is over Very Low Frequency using two transmitters at Skelton and Anthorn in Cumbria.

The Strategic Weapons System Integrated Project Team (SWS IPT) at Abbey Wood in Bristol provides logistical support for the Trident programme.

MODERNIZATION

In December 2006 President Bush wrote to Prime Minister Blair, agreeing to support the British nuclear weapon programme. Bush referred to "the steps outlined in your letter to maintain and modernize the U.K.'s capability in this area for the longer term".[30]

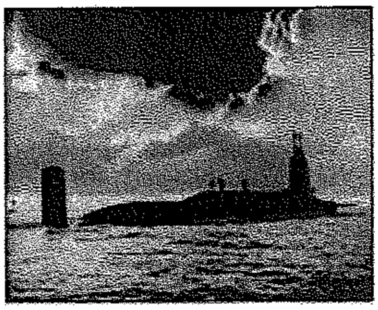
Warheads

Warhead Modification Program (Mk4A)

The US Departments of Energy and Defence have a joint program to upgrade their W76-0/Mk4 warheads to a new W76-1/Mk4A specification. In 2007 there was a UK project called the "Mk4A refurbishment programme".[31] Annual reports from the Defence Nuclear Environmental and Safety Board in 2006–2008 referred to a "Warhead Modification" program.[32] The 2006 report described this as "the planned modification of the nuclear warhead (principally the Mk4A AF&F upgrade)".[33] The AF&F is the Arming, Fusing, and Firing system. The annual report from the Nuclear Weapons Regulator for 2004/5 also mentioned the "introduction of replacement AF&F".[34]

Defence Ministers Lewis Moodie and John Reid failed to disclose the existence of the Mk4A upgrade project when questioned by Members of Parliament in 2002 and 2006.[35] The MoD mentioned "some relatively minor upgrading and refurbishment" of the Trident

ANNEX 13 – The Strategic Defence Review, published on 8 July 1998 Cm 3999



Trident submarine, HMS VICTORIOUS, on trials.

63. Similarly, we must judge our weapons requirements against the worst circumstances that we might face over Trident's life, however remote they may seem today. The credibility of deterrence also depends on retaining an option for a limited strike that would not automatically lead to a full scale nuclear exchange. Unlike Polaris and Chevaline, Trident must also be capable of performing this 'sub-strategic' role.

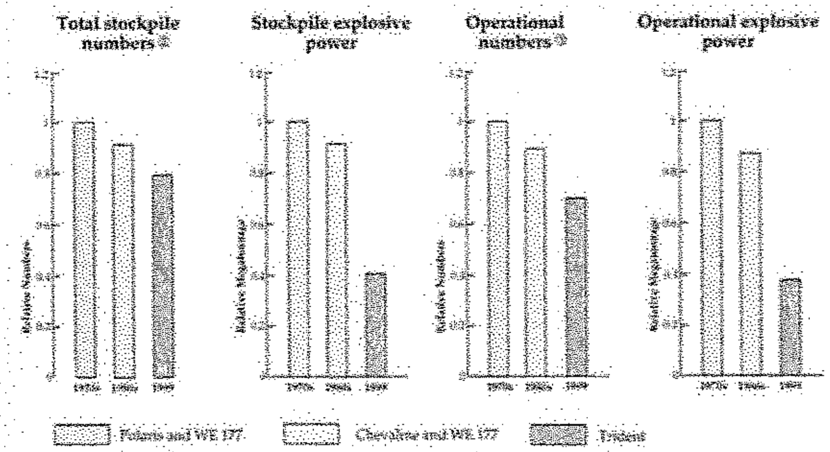
64. Against this background, taking into account Trident's greater accuracy than Polaris, the Review has concluded that we need a stockpile of less than 200 operationally available warheads. This is a reduction of a third from the maximum of 300 announced by the previous government and represents a reduction of more than 70% in the potential explosive power of the deterrent since the end of the Cold War.

ANNEX 14 – Ministry of Defence, Statement on the Defence Estimates 1995, Cm 2800 (HMSO: London, 1995), https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/273324/2800.pdf

be deployed, will be 30% fewer and the explosive power of those operational warheads will be 62% less than in the 1970s. British nuclear forces will then comprise fewer than 300 operational or available warheads.

5. These figures demonstrate that the United Kingdom has reduced the size of its nuclear forces when circumstances have allowed. They also show that, far from being an increase in our nuclear arsenal, Trident will represent a much smaller deterrent, matched to our current security needs. Even when the START II reductions agreed between the United States and Russia are fully implemented, British nuclear forces will represent less than 10% of the nuclear forces available to the United States or Russia.

Figure 6. Reductions in the United Kingdom's Nuclear Deterrent ①



Notes

① The charts compare our planned nuclear force levels for the 1970s, 1980s and at 1999 when all WE 177 weapons will have been withdrawn from service. The charts do not include United States' systems formerly operated by the United Kingdom under dual key arrangements.

② The figures for total stockpile numbers include the total number of United Kingdom nuclear weapons in service excluding only any awaiting final breakdown.

③ The figures for operational numbers additionally exclude missile warheads held as a necessary processing margin or for surveillance purposes.

ANNEX 15

ANNEX 15 – The Strategic Defence and Security Review, published on 19 October 2010 Cm 7948, https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/62482/strategic-defence-security-review.pdf

assurance would not apply to any state in material breach of those non-proliferation obligations. We also note that while there is currently no direct threat to the UK or its vital interests from states developing capabilities in other weapons of mass destruction, for example chemical and biological, we reserve the right to review this assurance if the future threat, development and proliferation of these weapons make it necessary.

Value for money

3.8 In December 2006, the previous Government published *The Future of the United Kingdom's Nuclear Deterrent White Paper* (Cm6994). In March 2007 Parliament voted to retain a minimum nuclear deterrent based on the current Trident missile delivery system. Under the previous Government, work started on a programme to replace the current Vanguard class submarines when they leave service in the late 2020s. In May this year the Coalition programme for government stated that 'we will maintain Britain's nuclear deterrent, and have agreed that the renewal of Trident will be scrutinised to ensure value for money. Liberal Democrats will continue to make the case for alternatives'. The value for money review has now been completed.

3.9 The Government will maintain a continuous submarine-based deterrent and begin the work of replacing its existing submarines. We will therefore proceed with the renewal of Trident and the submarine replacement programme, incorporating the savings and changes set out below. The first investment decision (Initial Gate) will be approved, and the next phase of the project commenced, by the end of this year.

3.10 The review has concluded that the overall cost of the submarine and warhead replacement programmes and associated infrastructure remains within the £20 billion cost estimate foreseen in 2006 at 2006 prices. To drive value for money we will:

- defer decisions on a replacement to the current warhead
- reduce the cost of the replacement submarine missile compartment
- extend the life of the current Vanguard class submarines and re-profile the programme to build replacement submarines
- consequently, take the second investment decision (Main Gate) finalising the detailed acquisition plans, design and number of submarines around 2016
- work with British industry to improve efficiency and optimise to expected demand its capacity to build and support submarines.

As a result of our reassessment of the minimum necessary requirements for credible deterrence we will:

- reduce the number of warheads onboard each submarine from 48 to 40
- reduce our requirement for operationally available warheads from fewer than 160 to no more than 120
- reduce our overall nuclear weapon stockpile to no more than 180
- reduce the number of operational missiles on each submarine.

The overall impact of the changes identified by the value for money review will be to reduce costs by £3.2 billion, saving approximately £1.2 billion and deferring spending of up to £2 billion from the next 10 years; we expect some of the deferred spend ultimately to be translated into real savings in later years. These savings do not alter in any way the nature and credibility of the nuclear deterrent, including maintenance of Continuous At Sea Deterrence. Further detail is set out below.

Scale

3.11 The Government has concluded that we can meet the minimum requirement of an effective and credible level of deterrence with a smaller nuclear weapons capability. We will therefore cut the maximum number of nuclear warheads onboard each deployed submarine from 48 to 40. Together with improved stockpile management, that will reduce our requirement for operationally available warheads from fewer than 160 to no more than 120. We will also reduce the number of operational missiles on the Vanguard class

ANNEX 16 – Stockholm International Peace Research Institute (SIPRI)
http://www.sipri.org/research/armaments/nuclear-forces

Read the full press release.

Overall inventories are declining, primarily due to the United States and Russia continuing the drawdown of their nuclear arsenals as a result of the Treaty on Measures for the Further Reduction and Limitation of Strategic Offensive Arms (New START) and unilateral reductions. But the pace of reductions appears to be slowing compared with a decade ago. At the same time, all the nuclear-armed states are modernizing their remaining nuclear forces and appear determined to retain sizeable nuclear arsenals for the foreseeable future.

The USA and Russia continue to reduce their arsenals but at a slower pace than a decade ago and have extensive modernization programs underway for their remaining nuclear delivery systems, warheads, and production facilities. The nuclear arsenals of the other smaller nuclear-armed states are considerably smaller, but all are either developing or deploying new weapons or have announced their intention to do so.

Reliable information on the status of the nuclear arsenals and capabilities of the nuclear-armed states varies considerably. The USA has disclosed substantial information about its stockpile and forces, and the UK and France have also declared some information. Russia refuses to disclose the detailed breakdown of its forces counted under the New START treaty (even though it shares the information with the USA), and the US Government has stopped releasing detailed information about Russian and Chinese nuclear forces.

China, India and Pakistan are the only nuclear weapon states that are expanding their nuclear arsenals, while Israel appears to be waiting to see how the situation in Iran develops. There is an emerging consensus in the expert community that North Korea has produced a small number of nuclear weapons, as distinct from rudimentary nuclear explosive devices.

World nuclear forces, January 2014

All estimates are approximate.

Country	Year of first nuclear test	Deployed warheads[a]	Other warheads	Total Inventory
United States	1945	1920	5380	7300
Russia	1949	1600	6400	8000
United Kingdom	1952	160	65	225
France	1960	290	10	300
China	1964	..	250	250
India	1974	..	90–110	90–110
Pakistan	1998	..	100–120	100–120

ANNEX 17 – Hansard, HC, 20 January 2015, col. 4WS (HCWS210), http://www.publications.parliament.uk/pa/cm201415/cmhansrd/cm150120/wmstext/150120m0001.htm#15012039000023

UK Statistics Authority

The Minister for Civil Society (Mr Rob Wilson): The Cabinet Office wishes to report that a cash advance from the Contingencies Fund has been sought for the UK Statistics Authority (referred to as the Statistics Board in the Statistics and Registration Service Act 2007). The advance is required in order to settle material liabilities arising from an anticipated reduction of the year end creditor balance.

Parliamentary approval for additional resources of £35,000 will be sought in a supplementary estimate for the Statistics Board. Pending that approval, urgent expenditure estimated at £14,249,000 will be met by repayable cash advances from the Contingencies Fund.

[HCWS208]

TREASURY

Double Taxation Agreement (Croatia)

The Financial Secretary to the Treasury (Mr David Gauke): A double taxation agreement and protocol with Croatia was signed on 15 January 2015. The text of the agreement and protocol has been deposited in the Libraries of both Houses and made available on HM Revenue and Customs' website. The text will be scheduled to a draft Order in Council and laid before the House of Commons in due course.

It is also available online at: http://www.parliament. uk/writtenstatements

[HCWS209]

20 Jan 2015 : Column 4WS

DEFENCE

Nuclear Deterrent

The Secretary of State for Defence (Michael Fallon): As part of his statement on the strategic defence and security review (SDSR) on 19 October 2010, my right hon. Friend the Prime Minister announced that we had reviewed our nuclear deterrence requirements. He concluded that we could deliver a credible nuclear deterrent with a smaller nuclear weapons capability and would incorporate these reductions into the current deployed capability and the future successor deterrent programme. The number of deployed warheads on each submarine would be reduced from 48 to 40; the number of operational missiles in the Vanguard class ballistic missile submarines (SSBN) would be reduced to no more than eight; and we would reduce the number of operationally available warheads from fewer than 160 to no more than 120.

The then Secretary of State for Defence, my right hon. Friend the Member for North Somerset (Liam Fox), announced to the House on 29 June 2011, *Official Report*, columns 50-51WS, that the programme for implementing the 2010 SDSR warhead reductions had commenced.

I am pleased to inform the House that this Government have now met their commitment to

ANNEX 18

ANNEX 18 – Hansard, HC Deb, 20 January 2015, col. 105, http://www.publications.parliament.uk/pa/cm201415/cmhansrd/cm150120/debtext/150120-0002.htm

deterrent based on continuous at-sea deterrence, and of course we want to provide it in the most cost-effective way possible. Indeed, when he reads

Hansard

tomorrow, the Defence Secretary will find that that is exactly what he said a few moments ago.

Michael Fallon: I think that the House will be grateful to the hon. Gentleman for clarifying that he is still committed to a continuous at-sea deterrent. I hope that he will send a copy of those words to the Leader of the Opposition, so that there can no longer be any lingering doubt in Scotland about whether or not this is a continuous at-sea deterrent.

Mr Spellar: The right hon. Gentleman is putting up a sterling smokescreen for the Government's position, as many of his Back-Bench colleagues know. He talks of coalitions. He is not getting on with this because he is in an unholy coalition with the Liberal Democrats, who are preventing him from taking action. He is making a good show of it, but, as he says that he is being clear, let him now be clear to the House.

Michael Fallon: The right hon. Gentleman anticipates me, because I now want to turn—indeed, I think we all now want to turn—to the position of the Liberal Democrats. On one hand, the Liberal Democrats have said that they want to spend billions to

"replace some of the submarines",

and to make our deterrent part time. They have also committed themselves—at their most recent conference—to allowing our submarines to go to sea with unarmed missiles. Those would be pointless patrols, and that is a pointless nuclear deterrent policy. There are no Liberal Democrats in the Ministry of Defence, and the fact that they have adopted such a reckless and, frankly, dangerous approach explains why.

This country faces the threat of nuclear blackmail from rogue states. It is therefore contemptible for the Scottish nationalists or the Liberal Democrats to suggest that they might use the ultimate guarantor of our freedom and independence as some kind of bargaining chip in some grubby coalition deal. To put it more simply, it is only the Conservative party that will not gamble with the security of the British people.

Dr Julian Lewis: While the Secretary of State is dealing with the Liberal Democrats—only two of whom I see in the Chamber today—will he confirm that a policy of sending unarmed submarines to sea and waiting for a crisis to arise, then sending them back to port to be rearmed while the enemy stands idly by, is actually more dangerous than a policy of keeping them in port all along? Will he also confirm that there will never again be a deal between the Conservatives and the Liberal Democrats to delay the maingate decision, as there was in 2010? That is something with which he had nothing to do, but which should never have been allowed to happen.

Michael Fallon: Let me assure my hon. Friend, in response to his first point, that we are not planning to make future deals of any kind with the Liberal Democrats. On the contrary, we hope to be returned in May with an absolute majority that will restore defence policy to the hands of a Conservative Government. As for my hon.

20 Jan 2015 : Column 105

ANNEX 19 – Hansard, HC Deb, 18 October 1993, col. 34, http://www.publications.parliament.uk/pa/cm199293/cmhansrd/1993-10-18/Debate-2.html

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Column 34

by £1 billion while social security expenditure has increased in real terms by £29 billion? That is more than the entire defence budget.

If the Chancellor must look for areas in which to cut expenditure, should not he look first at the abuse of social security?

Mr. Rifkind : I do not wish to comment on what the appropriate level of social security expenditure should be. One can point to the effective way in which the Government have been responsible for the defence of the realm during the past 14 years. Conservative Governments have never treated defence lightly, and I believe that they never will.

The White Paper has also confirmed our commitment to maintaining an effective long-term sub-strategic nuclear capability. I told the House some months ago that we were considering how best to provide this once the WE177 free-fall bomb is withdrawn from service. Our considerations were completed during the recess, and I am able to announce our conclusions today.

A sub-strategic capability remains necessary, because a potential adversary might gamble, under certain circumstances, on our reluctance to launch an all-out strategic nuclear strike in response to his aggression. It is vital, therefore, that we possess the ability to undertake more limited nuclear action, to be able to deliver an unequivocal message to an aggressor that he must cease his aggression and withdraw or face the risk of even greater damage. A sub-strategic capability forms an essential link between conventional and strategic forces, as part of our clear demonstration that aggression of any kind is not a rational option.

The United Kingdom's sub-strategic capability is currently provided by the WE177 bomb carried on Tornado dual-capable aircraft. In the mid to late 1980s, we saw the need to enter into the early development of a sophisticated stand-off weapon which would be able to penetrate the increasingly effective Warsaw pact defences, and which would replace the current bomb. The type of system we began to examine is known as a tactical air-to-surface missile, or TASM. The security circumstances have changed fundamentally since then. As a consequence, we have concluded that our previous requirement for a new stand-off nuclear weapon capability is not a sufficiently high priority to justify the procurement of a new nuclear system in the current circumstances. Instead, we will plan, after the WE177 eventually leaves service in the long term, on exploiting the flexibility and capability of the Trident system to provide the vehicle for the delivery of our sub-strategic deterrent.

The Trident system is undetectable, reliable, and accurate in its delivery and can carry our sub-strategic as well as strategic capacity at little additional cost. That is set against what would be the high cost of developing a new system. We have no doubt that it will be admirably suited to the additional role.

Mr. John Wilkinson (Ruislip-Northwood) : My right hon. and learned Friend is announcing an exceedingly important decision, which will effectively end the historic role of the Royal Air Force as the primary instrument of at least sub-strategic deterrence.

Why have the Government come to a different conclusion from the defence strategists of France, the

ANNEX 20 – Text of Letters exchanged between the Prime Minister and the President of the United States and between the Secretary of State for Defence and the US Secretary of Defense. The letters are reproduced in 'Polaris Sales Agreement between the United States and the United Kingdom' signed in Washington on 6 April 1963, www.nuclearinfo.org/sites/default/files/Polaris%20Sales%20Agreement%201963.pdf

UNITED STATES

Treaty Series No. 59 (1963)

Polaris Sales Agreement

between the Government of the
United Kingdom of Great Britain and Northern Ireland
and the Government of the United States of America

Washington, April 6, 1963

[The Agreement entered into force on signature]

Presented to Parliament by the Secretary of State for Foreign Affairs
by Command of Her Majesty
August 1963

LONDON
HER MAJESTY'S STATIONERY OFFICE
ONE SHILLING NET

Cmnd. 2108

POLARIS SALES AGREEMENT BETWEEN THE GOVERNMENT OF THE UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND AND THE GOVERNMENT OF THE UNITED STATES OF AMERICA

The Government of the United Kingdom of Great Britain and Northern Ireland and the Government of the United States of America, recalling and affirming the "Statement on Nuclear Defense Systems" (1) included in the joint communiqué issued on December 21, 1962, by the Prime Minister of Her Majesty's Government in the United Kingdom of Great Britain and Northern Ireland and the President of the United States of America, have agreed as follows:—

ARTICLE I

1. The Government of the United States shall provide and the Government of the United Kingdom shall purchase from the Government of the United States Polaris missiles (less warheads), equipment, and supporting services in accordance with the terms and conditions of this Agreement.

2. This Agreement shall be subject to the understandings concerning British submarines equipped with Polaris missiles (referred to in paragraphs 8 and 9 of the Nassau "Statement on Nuclear Defense Systems") agreed by the President of the United States and the Prime Minister at their meeting held in the Bahamas between December 18 and 21, 1962.

ARTICLE II

1. In recognition of the complexity of the effort provided for in this Agreement and the need for close coordination between the contracting Governments in giving effect to its terms, the two Governments shall promptly establish the organizational machinery provided for in the following paragraphs of this Article.

2. The Department of Defense, acting through the Department of the Navy, and the Admiralty, or such other agency as the Government of the United Kingdom shall designate, will be the Executive Agencies of their respective Governments in carrying out the terms of this Agreement. Appropriate representatives of the Executive Agencies are authorized to enter into such technical arrangements, consistent with this Agreement, as may be necessary.

3. A Project Officer will be designated by each Government's Executive Agency with direct responsibility and authority for the management of the activities of that Government under this Agreement. Each Project Officer will designate liaison representatives, in such numbers as may be agreed, who will be authorized to act on his behalf in capacities specified in technical arrangements and who will be attached to the Office of the other Project Officer.

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(1) Cmnd. 1915

4. A Joint Steering Task Group will be established by the Project Officers to advise them, *inter alia*, concerning the development of new or modified equipment to meet specific requirements of the Government of the United Kingdom, and concerning interfaces between the equipment provided by the two Governments respectively. The Joint Steering Task Group will comprise the Project Officers (or their representatives), and principal liaison representatives, and may include selected leaders from among the scientists, industrialists and government executives of the United Kingdom and of the United States. The Joint Steering Task Group will meet approximately every three months alternately in the United Kingdom and in the United States under the chairmanship of the resident Project Officer.

Article III

1. The Government of the United States (acting through its Executive Agency) shall provide, pursuant to Article I of this Agreement, Polaris missiles (less warheads), equipment, and supporting services of such types and marks and in such quantities as the Government of the United Kingdom may from time to time require, and in configurations and in accordance with delivery programs or time tables to be agreed between the Project Officers. In the first instance the missiles, equipment, and supporting services provided by the Government of the United States shall be sufficient to meet the requirements of a program drawn up by the Government of the United Kingdom and communicated to the Government of the United States prior to the entry into force of this Agreement.

2. The missiles, equipment, and supporting services referred to in paragraph 1 of this article are the following:

a. Polaris missiles (less warheads but including guidance capsules) ;

b. missile launching and handling systems ;

c. missile fire control systems ;

d. ships navigation systems ;

e. additional associated, support, test, and training equipment and services including, but not limited to:

(i) test and check-out equipment, specialized power supplies, power distribution systems and support equipment associated with the items enumerated in subparagraphs a, b, c, and d, of this paragraph and adequate in type and quantity to meet the requirements of installations both aboard ship and ashore ;

(ii) specialized equipment including the types specified in subparagraphs a, b, c, d, and e.(i) of this paragraph for use in such support and training facilities as may be provided by the Government of the United Kingdom ;

(iii) construction spares and spare parts adequate in scope and quantity to ensure the continued maintenance of the equipment specified in subparagraph a, b, c, d, e.(i), and e.(ii) of this paragraph ;

(iv) (a) latest available United States technical documentation including specifications, blueprints, and manuals covering the missiles and equipment listed in subparagraphs a, b, c, d, e (i), e (ii) and e (iii) of this paragraph in sufficient scope and quantity to cover safety requirements and permit successful transport, installation, operation, and maintenance by the Government of the United Kingdom of all equipment purchased under the terms of this Agreement;

(b) latest available United States technical documentation, as may be necessary from time to time in individual cases, to permit manufacture by the Government of the United Kingdom to the extent necessary for the maintenance, repair, and modification of the items listed in subparagraphs a, b, c, d, e.(i), e.(ii) and e.(iii) of this paragraph;

(v) services, including:

(a) use, as appropriate, of existing support and missile range facilities in the United States;

(b) assistance in program management techniques and, in addition, those engineering and lead shipyard services required to ensure proper system integration, installation, and check-out in the United Kingdom; to the extent required and available, appropriate modification, maintenance, and overhaul of the equipment listed in subparagraph a, b, c, d, e.(i), e.(ii), e.(iii) of this paragraph;

(c) research, design, development, production, test, or other engineering services as may be required to meet specific United Kingdom requirements;

(d) training of naval and civil personnel in the service of the Government of the United Kingdom and United Kingdom contractors to the extent to which they are involved in the inspection, installation, operation, maintenance, repair, and modification of the equipment listed in subparagraphs a, b, c, d, e.(i) e.(ii), and e.(iii) of this paragraph.

ARTICLE IV

Future developments relating to the Polaris Weapon System, including all modifications made thereto, by the Government of the United Kingdom or the Government of the United States shall, in the areas enumerated in Article III, be made reciprocally available through their Executive Agencies in accordance with the terms of this Agreement, reciprocally applied.

ARTICLE V

The Government of the United Kingdom will provide the submarines in which will be installed the missiles and equipment to be provided under this Agreement, and will provide the warheads for these missiles. Close coordination between the Executive Agencies of the contracting Governments will be maintained in order to assure compatibility of equipment. Information concerning the hull, auxiliary machinery, and equipment of United States submarines transmitted under the authority of this Agreement will be such as is necessary to obtain a satisfactory interface between the equipment provided by the two Governments respectively. This Agreement does not, however, authorize the sale of, or transmittal of information concerning, the nuclear propulsion plants of United States submarines.

Article VI

1. In carrying out this Agreement, the Government of the United States will use, to the extent practicable, established Department of Defense contracting procedures and existing Polaris contracts. In any event contracts for production or work for the Government of the United Kingdom will be incorporated in or placed on the same terms as those for the Government of the United States. When appropriate the United States Project Officer will direct that amendments be sought to existing contracts and that terms be incorporated in new contracts to safeguard any special requirements of the Government of the United Kingdom in the contract subject matter which may arise in connection with this Agreement, for example, to provide for any alterations or any reduction of quantities which may be necessary.

2. The missiles and equipment provided by the Government of the United States under this Agreement shall be fabricated to the same documentation and quality standards as are the counterparts for the United States Polaris Program.

3. The missiles and equipment provided by the Government of the United States under this Agreement will be integrated with the scheduled United States Polaris Program and will be fabricated on a schedule which will make the most efficient and economical use of existing United States production lines. Deliveries will be made upon a schedule to be defined by the Government of the United Kingdom, but which is consonant with the above fabrication schedule.

Article VII

1. The Government of the United States shall ensure that all supplies (which term throughout this Article includes, but without limitation, raw materials, components, intermediate assemblies and end items) which it will provide under this Agreement are inspected to the same extent and in the same manner (including the granting of waivers and deviations) as are the counterparts for the United States Polaris Program. The United Kingdom Project Officer or his designated representative may observe the inspection process and offer his advice to the United States Government Inspector regarding the inspection, without delay to, or impairment of the finality of, the inspection by the Government of the United States.

2. The United States Project Officer through appropriate procedures will notify the United Kingdom Project Officer when final inspection of each end item will take place, and will furnish a certificate or certificates upon completion of each such inspection stating that this inspection has been made and that such end item has been accepted as having met all requirements of the relevant acceptance documentation (subject to any appropriate waivers

and deviations). Copies of acceptance documentation and quality standards, together with reports required thereby, will be furnished to the United Kingdom Project Officer or his designated representative.

3. The Government of the United Kingdom will take delivery of the supplies as agreed pursuant to Article X following inspection, acceptance and certification by the Government of the United States. Delivery to the Government of the United Kingdom shall not relieve the Government of the United States from continuing responsibility for using its best endeavors thereafter to secure the correction or replacement of any items found not to have been manufactured in strict accordance with the documentation and quality standards referred to in Article VI or to be otherwise defective. Such corrections or replacements will be at the expense of the Government of the United Kingdom to the extent they are not covered by warranty or guaranty or otherwise recoverable by the Government of the United States.

4. The Government of the United States will use its best endeavors to obtain for or extend to the Government of the United Kingdom the benefit of any guarantees or warranties negotiated with United States contractors or subcontractors.

Article VIII

The Government of the United Kingdom shall indemnify and hold harmless the Government of the United States against any liability or loss resulting from unusually hazardous risks attributable to Polaris missiles or equipment identifiable, respectively, as missiles or equipment supplied or to be supplied to the Government of the United Kingdom under this Agreement. Unusually hazardous risks, for the purposes of this Agreement, are those defined by applicable statutes of the United States, or by any appropriate administrative act under the authority of such statutes, or held to exist by a court of competent jurisdiction. The Government of the United States shall give the Government of the United Kingdom immediate notice of any suit or action filed or of any claim made to which the provisions of this Article may be relevant. Representatives of the United Kingdom may be associated with the defense, before a court of competent jurisdiction, of any claim which may be borne in whole or in part by the Government of the United Kingdom. In procurement contracts for supplies and services made pursuant to this Agreement the Government of the United States is authorized to include unusually hazardous risk indemnification provisions substantially similar to those included in its own corresponding contracts.

Article IX

1. The Government of the United States will follow its normal procurement practices in securing all rights it considers to be essential to enable it to provide the missiles and equipment to be supplied to the Government of the United Kingdom under this Agreement. In addition, the Government of the United States shall notify the Government of the United Kingdom of any claim asserted hereafter for compensation for unlicensed use of patent rights alleged to be involved in the supply of such missiles and equipment to the Government of the United Kingdom, and the two Governments will consult as to the appropriate disposition of such claim.

2. The Government of the United Kingdom shall reimburse the Government of the United States for any payments made by the Government of the United States in settlement of liability, including cost and expenses, for unlicensed use of any patent rights in the manufacture or sale of the missiles and equipment supplied or to be supplied to the Government of the United Kingdom under this Agreement.

Article X

1. Delivery of equipment other than missiles to be provided under this Agreement for installation in submarines or supporting facilities to be provided by the Government of the United Kingdom shall be the responsibility of the Government of the United States and shall be made to those locations within the United Kingdom where the equipment is required. In addition to delivery of such equipment, the Government of the United States shall, subject to reimbursement for costs incurred, be responsible for providing such technical installation and testing services as are required by the Government of the United Kingdom for the satisfactory installation, check-out and testing of that equipment in submarines and supporting facilities of the United Kingdom.

2. Delivery of all missiles shall be made to appropriate carriers of the United Kingdom or, if it is agreed, of the United States, at such United States supply points as are agreed by the Executive Agencies of both Governments. The Government of the United States shall be responsible for the initial check-out of all missiles provided under this Agreement.

Article XI

1. The charges to the Government of the United Kingdom for missiles, equipment, and services provided by the Government of the United States will be:

a. The normal cost of missiles and equipment provided under the joint United States-United Kingdom production program integrated in accordance with Article VI. This will be based on common contract prices together with charges for work done in United States Government establishments and appropriate allowance for use of capital facilities and for overhead costs.

b. An addition of 5% to the common contract prices under subparagraph 1.a. of this Article for missiles and equipment provided to the United Kingdom, as a participation in the expenditures incurred by the Government of the United States after January 1, 1963, for research and development.

c. Replacement cost of items provided from United States Government stock or, with respect to items not currently being procured, the most recent procurement cost.

d. The actual cost of any research, design, development, production, test or other engineering effort, or other services required in the execution of this Agreement to meet specific United Kingdom requirements.

e. The cost of packing, crating, handling and transportation.

f. The actual costs of any other services, not specified above, which the Project Officers agree are properly attributable to this Agreement.

2. Payments by the Government of the United Kingdom in accordance with paragraph 1. of this Article shall be made in United States dollars. Payments to United States agencies and contractors shall be made, as they become due, from a trust fund which will be administered by the United States Project Officer. All payments out of the Trust Fund shall be certified to be in accordance with the terms of the Agreement. The Trust Fund will consist initially of a sum to be paid as soon as possible after entry into force of this agreement and to be equivalent to the payments estimated to fall due during the first calendar quarter of programme operations. Before the end of that quarter and of each succeeding quarter deposits shall be made by the Government of the United Kingdom with the object of having sufficient money in the Fund to meet all the calls which will be made upon it in the succeeding three months.

3. If at any time, the unexpended balance in the Trust Fund established pursuant to paragraph 2. of this Article falls short of the sums that will be needed in a particular quarter by the Government of the United States to cover ;

a. payment for the value of items to be furnished from the stocks of, or services to be rendered by, the Government of the United States ;

b. payment by the Government of the United States to its suppliers for items and services to be procured for the Government of the United Kingdom ; and

c. estimated liability or costs that may fall to be met by the Government of the United States as a result of termination of such procurement contracts at the behest of the Government of the United Kingdom :

the Government of the United Kingdom will pay at such time to the Government of the United States such additional sums as will be due. Should the total payments received from the Government of the United Kingdom prove to be in excess of the final total costs to the Government of the United States, appropriate refund will be made to the Government of the United Kingdom at the earliest opportunity with final adjustment being made within thirty days after determination of said final costs.

4. The United States Project Officer will maintain a record of expenditures under this Agreement in accordance with established Navy Special Projects Office Accounting procedures which record will be available for audit annually by representatives of the Government of the United Kingdom.

Article XII

1. The provisions of this Article concerning proprietary rights shall apply to the work referred to in subparagraph 1.d. of Article XI of this Agreement (hereinafter called in this Article " the work ").

2. The Government of the United States shall ensure that the Government of the United Kingdom will receive a royalty-free, non-exclusive, irrevocable license for its governmental purposes:

a. to practice or cause to be practiced throughout the world, all inventions conceived or first actually reduced to practice in the performance of the work ; and

b. to use or cause to be used throughout the world, all technical information first produced in the performance of the work.

3. In addition, the Government of the United States shall take the following steps to ensure the right of the Government of the United Kingdom to reproduce, by manufacturers of its own choice, items developed in the performance of the work. In respect of those elements of this right not included in subparagraphs 2.a. and 2.b. of this Article, the Government of the United States shall:

a. to the extent that it owns or controls such elements, accord free user rights to the Government of the United Kingdom ;

b. obtain the agreement of contractors and subcontractors performing the work to make available to the Government of the United Kingdom, on fair and reasonable terms and conditions, those elements which the contractor or subcontractor owns or controls at the commencement of the work or acquires during the performance of the work ;

c. use its best endeavors to obtain for the Government of the United Kingdom or to assist the Government of the United Kingdom to obtain directly or through its own manufacturers, on fair and reasonable terms and conditions, elements of this right not covered by subparagraphs 2.a. and 2.b. of this Article.

4. The Government of the United States shall also ensure that the Government of the United Kingdom will receive the same rights as those referred to in paragraphs 2. and 3. of this Article in respect of any material now or hereafter covered by copyright produced or delivered in the performance of the work.

5. The Government of the United States shall furnish to the Government of the United Kingdom, in such quantities as may be agreed:

a. all documentation obtained by the Government of the United States under contracts placed for the performance of the work ;

b. all documentation, owned or controlled by the Government of the United States, necessary for reproduction, by or on behalf of the Government of the United Kingdom, of items developed during the performance of the work.

6. It is understood that the Government of the United States will obtain for itself such of the rights referred to in subparagraphs 2.a., 2.b., and 3. of this Article as it may require for its governmental purposes.

7. The term " owned or controlled " as used in this Article means the right to grant a licence without incurring liability to any private owner of a proprietary or other legal interest.

8. The Government of the United States will use its best endeavors to ensure that there will be made available by United States manufacturers to the Government of the United Kingdom, on fair and reasonable terms and conditions, such technical assistance—for example, loan of engineers, or training—as the Government of the United Kingdom desires in order to permit the production by manufacturers of its own choice of the items developed in the performance of the work.

9. The Government of the United States will insert suitable provisions in all prime contracts for the work to ensure the availability to the Government of the United Kingdom of the rights, set forth in this Article, including a requirement that similar provisions be placed in subcontracts.

ARTICLE XIII

1. The Government of the United States, to the extent that it can do so without incurring liability to any private owner of a proprietary or other legal interest, shall grant to the Government of the United Kingdom: (i) the right to reproduce and use, royalty-free, the technical documentation referred to in subparagraph 2.e.(iv) of Article III for the purposes stated in that subparagraph ; and (ii) a non-exclusive, royalty-free licence to practice or cause to be practiced any invention for these purposes.

2. In respect of any part of the technical documentation referred in paragraph 1 of this Article which the Government of the United States cannot furnish to the Government of the United Kingdom without incurring a liability to a private owner of a proprietary or other legal interest, the Government of the United States will use its best endeavours to assist the Government of the United Kingdom in securing for the Government of the United Kingdom on fair and reasonable terms and conditions the right to use such documentation for the purposes stated in subparagraph 2.e.(iv) of Article III.

ARTICLE XIV

1. The Government of the United Kingdom shall not, without the prior express consent of the Government of the United States, transfer, or permit access to, or use of, the missiles, equipment, services, or documents or information relating thereto which are provided by the Government of the United States under this Agreement, except to a United Kingdom officer, employee, national or firm engaged in the implementation of this Agreement.

2. The Government of the United Kingdom shall undertake such security measures as are necessary to afford classified articles, services, documents or information substantially the same degree of protection afforded by the Government of the United States in order to prevent unauthorized disclosure or compromise.

ARTICLE XV

Annually, on or before the first of July, the Project Officers will prepare a formal joint report to the contracting Governments of action taken and progress made under this Agreement and a forecast of schedules and costs for completion. In addition, other more frequent joint reports will be submitted, as agreed upon by the Project Officers, to the heads of the Executive Agencies.

ARTICLE XVI

This Agreement shall enter into force on the date of signature.

IN WITNESS WHEREOF the undersigned, being duly authorized thereto by their respective Governments, have signed this Agreement.

DONE in duplicate at Washington this sixth day of April, 1963.

For the Government of the United Kingdom of
Great Britain and Northern Ireland:
D. ORMSBY GORE

For the Government of the United States of America:
DEAN RUSK

19803—64 2664 Wt. 425/102 K12 8/63 F.O.P.

ANNEX 21 – "The Alliance's Strategic Concept", NATO Press Release NAC-S(99)65, April 24 1999,
www.nato.int/cps/en/natolive/official_texts_27433.htm

and other countries may participate;

d. that overall, the Alliance will, in both the near and long term and for the full range of its missions, require essential operational capabilities such as an effective engagement capability; deployability and mobility; survivability of forces and infrastructure; and sustainability, incorporating logistics and force rotation. To develop these capabilities to their full potential for multinational operations, interoperability, including human factors, the use of appropriate advanced technology, the maintenance of information superiority in military operations, and highly qualified personnel with a broad spectrum of skills will be important. Sufficient capabilities in the areas of command, control and communications as well as intelligence and surveillance will serve as necessary force multipliers;

e. that at any time a limited but militarily significant proportion of ground, air and sea forces will be able to react as rapidly as necessary to a wide range of eventualities, including a short-notice attack on any Ally. Greater numbers of force elements will be available at appropriate levels of readiness to sustain prolonged operations, whether within or beyond Alliance territory, including through rotation of deployed forces. Taken together, these forces must also be of sufficient quality, quantity and readiness to contribute to deterrence and to defend against limited attacks on the Alliance;

f. that the Alliance must be able to build up larger forces, both in response to any fundamental changes in the security environment and for limited requirements, by reinforcement, by mobilising reserves, or by reconstituting forces when necessary. This ability must be in proportion to potential threats to Alliance security, including potential long-term developments. It must take into account the possibility of substantial improvements in the readiness and capabilities of military forces on the periphery of the Alliance. Capabilities for timely reinforcement and resupply both within and from Europe and North America will remain of critical importance, with a resulting need for a high degree of deployability, mobility and flexibility;

g. that appropriate force structures and procedures, including those that would provide an ability to build up, deploy and draw down forces quickly and selectively, are necessary to permit measured, flexible and timely responses in order to reduce and defuse tensions. These arrangements must be exercised regularly in peacetime;

h. that the Alliance's defence posture must have the capability to address appropriately and effectively the risks associated with the proliferation of NBC weapons and their means of delivery, which also pose a potential threat to the Allies' populations, territory, and forces. A balanced mix of forces, response capabilities and strengthened defences is needed;

i. that the Alliance's forces and infrastructure must be protected against terrorist attacks.

ANNEX 22 – Hansard, HC, 22 May 2006, col. 1331W, http://www.publications.parliament.uk/pa/cm200506/cmhansrd/vo060522/text/60522w0014.htm#06052325000141

Nuclear Weapons

Norman Baker: To ask the Secretary of State for Defence whether it is his policy that UK nuclear weapons should not be used against a non-nuclear state. [71942]

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Des Browne: The United Kingdom's policy has not changed since 1998. I refer the hon. Member to paragraph 31 of Supporting Essay 5 to the 1998 Strategic Defence Review.

Norman Baker: To ask the Secretary of State for Defence what the explosive yield is of the Trident warhead. [71943]

Des Browne: I am withholding the information requested because it relates to national security and defence of the UK.

Norman Baker: To ask the Secretary of State for Defence whether UK nuclear scientists are involved in the research and development of new US nuclear weapons, with particular reference to the Reliable replacement warhead. [71944]

Des Browne: The Reliable replacement warhead project is a purely US national programme.

Norman Baker: To ask the Secretary of State for Defence if he will make a statement on the *(a)* present and *(b)* future role of Trident, with particular reference to the potential development of a low yield warhead. [71945]

Des Browne: The Government's policy on nuclear weapons remains as set out in the 1998 Strategic Defence Review (SDR) (Cm 3999) and the 2002 SDR New Chapter (Cm 5566). The UK's nuclear weapons have a continuing use as a means of deterring major strategic military threats and they have a continuing role in guaranteeing the ultimate security of the UK. We would only ever contemplate their use in extreme circumstances of self-defence.

The Atomic Weapons Establishment is not engaged in the development of any new warheads.

Norman Baker: To ask the Secretary of State for Defence whether it is Government policy that first strike use of UK nuclear weapons is ruled out. [71989]

Des Browne: The United Kingdom Government would be prepared to use nuclear weapons only in extreme circumstances of self-defence. We would not use our weapons, whether conventional or nuclear, contrary to international law.

A policy of no first use of nuclear weapons would be incompatible with our and NATO's doctrine of deterrence. We have made clear, as have our NATO allies, that the circumstances in which any use of nuclear weapons might have to be contemplated are extremely remote. Our overall strategy is to ensure uncertainty in the mind of any aggressor about the exact nature of our response, and thus to maintain effective deterrence.

Norman Baker: To ask the Secretary of State for Defence for how long he estimates the UK Trident nuclear capability could remain operational were US technical support withdrawn. [71991]

Des Browne: We have not undertaken a detailed assessment of this hypothetical situation, as we have no

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reason to believe that the withdrawal of US technical support for Trident is remotely likely. However, we anticipate that, in this highly unlikely

ANNEX 23 – Hansard, HC Deb, 4 December 1997, cols. 576-577, http://www.publications.parliament.uk/pa/cm199798/cmhansrd/vo971204/debtext/71204-27.htm

4 Dec 1997 : Column 576

encouragement to believe that responsible nations have lost interest or lack the political will to respond to their transgressions.

On a more specific level, arms control agreements clearly have an important contribution in making proliferation both harder to achieve and harder to conceal. We welcome the agreement this year of increased powers for the International Atomic Energy Agency--the so-called "93 plus 2" programme. That will effectively fill the holes in which Saddam Hussein was able to hide his nuclear programme and make it more difficult for him or any successor to do so again. We are working for early implementation of that agreement.

The missile technology control regime--to which the right hon. Member referred--the nuclear non-proliferation treaty, the chemical weapons convention and the biological weapons convention all have a part to play. It is in our interests to encourage the widest possible support for those agreements, and to do what we can to strengthen the means available for monitoring, verifying and enforcing compliance.

Next year, we will be using our presidency of the European Union to press for early progress, particularly on verification arrangements for the biological weapons convention. It would be optimistic to imagine that arms control will completely eradicate the problem, but it will add to the obstacles faced by the would-be proliferator.

The right hon. Member will know that intelligence on such weapons has a critical part to play. The House will not expect me to go into details on the matter, but--on the basis that forewarned is forearmed--it is vital that we gather as much information as possible on proliferation activities, and particularly on the intentions and capabilities of potential adversaries. If there is the slightest chance that British armed forces might have to deploy to a particular region in future, in defence of British national interests or maintenance of international peace and security, we want and need to know as much as possible about the threats that they may have to face.

We must, however, accept that we will never be able to be sure that we know all that there is to know. Our approach to the issue must take account of that inevitable uncertainty.

When we do have good intelligence of capabilities and intentions, an additional element in our response may be the use of counter-force measures, to strike at the aggressor's capabilities before he can use them. Developments in precision guided and stand-off weapons may make that an increasingly viable option. We also have an exceptional asset in our special forces. However, the applicability of counter-force measures obviously depends on warning of the aggressor's intentions and the availability of good information for targeting purposes.

The role of deterrence, to which the right hon. Member referred, must not be overlooked. Even if a potential aggressor has developed missiles with the range to strike at the United Kingdom, and nuclear, biological or chemical warheads to be delivered by those means, he would have to consider--he would do well to consider--the possible consequences of such an attack.

There is sometimes a tendency to suppose that the concept of deterrence is relevant only in a transatlantic context, and that dictatorial regimes outside Europe are somehow incapable of thinking in such terms. We would be wise not to make such suppositions. Although such

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despots often appear indifferent to the suffering of their own peoples, I see no sign that they are indifferent to the survival of their regimes and the preservation of their personal positions. Deterrence has a bearing on both those matters.

It seems unlikely that a dictator who was willing to strike another country with weapons of mass destruction would be so trusting as to feel entirely sure that that country would not respond with the power at its disposal. Any state contemplating such an assault on a NATO member would have to consider the implications very carefully.

We must realise, however, that deterrence in that sense might not carry the same weight in all circumstances. Therefore, we need to be able to provide our forces with adequate protection for deployed operations, in case neither deterrence nor counter-force measures could be relied on to nullify the threat. Such protection could include both active and passive defensive measures. Active defence, as the right hon. Gentleman well knows, is generally used to refer to anti-missile defence systems, such as the Patriot system and various other systems being developed by the United States, together with the necessary early warning and command, control and communications capabilities.

We maintain close links with our American allies on this subject--very close, in fact. The right hon. Gentleman perhaps has no idea quite how close. Were I not addressing the Chamber on this important subject, I would be at a dinner with our Secretary of State and the United States Defence Secretary. The British Government will continue close links with our American allies; we have also played a full part in discussions in NATO, and will keep doing so.

At the national level, a consortium led by British Aerospace has conducted a pre-feasibility study investigating the various technical options that may become available in the years ahead. While the study remains classified, I am glad to tell the right hon. Gentleman that my officials are working to produce a declassified version of a report on the methodology and findings of the wider pre-feasibility programme, of which the study formed the larger part. That work has been part of the background to consideration of the issue under the strategic defence review.

There is a continuity of contemplation and purpose on this issue which does not square with the inaccurate reporting that formed part of the basis of the right hon. Gentleman's speech. I cannot yet tell the House

ANNEX 24 – Strategic Defence Review, New Chapter, 18 July 2002, Vol.1, para. 22, http://www.publications.parliament.uk/pa/cm200203/cmselect/cmdfence/93/93.pdf

22. Britain's nuclear weapons were identified as having a continuing use as a means of deterring a major strategic military threat and in guaranteeing the ultimate security of the UK, but at the same time all UK Armed Forces could be expected to contribute in different

[33] HC Deb, 18 July 2002, col 460.

[34] SDR NC Vol 1, para 5.

[35] SDR NC Vol 1, para 11.

[36] See chart on the MoD's conceptual approach to countering terrorism in Chapter 5 below.

[37] SDR NC Vol 1, para 21.

ways to the full spectrum of deterrence. The New Chapter did not announce in advance how Britain might respond to particular threats but merely stated that the response would be appropriate and proportionate—"It should be clear that legally the right to self defence includes the possibility of action in the face of an imminent attack".[38]

ANNEX 25 – *The Future of the UK's Nuclear Deterrent: the White Paper*, Ninth Report of Session 2006-07, Https://www.gov.uk/government/publications/the-future-of-the-united-kingdoms-nuclear-deterrent-defence-white-paper-2006-cm-6994

3-8. Currently no state has both the intent to threaten our vital interests and the capability to do so with nuclear weapons. However, the fact that such a conjunction does not exist today is not a reliable guide to the future. The risks set out above raise the possibility that, at some stage in the future, nuclear capabilities and hostile intent will become dangerously aligned. We can foresee nuclear risks in three specific areas:

Re-emergence of a Major Nuclear Threat

3-9. There are risks that, over the next 20 to 50 years, a major direct nuclear threat to the UK or our NATO Allies might re-emerge. A state's intent in relation to the use or threat of use of existing capabilities could change relatively quickly: for example, there was little prior warning of the collapse of the Soviet Union. We will continue to work actively with all our friends and partners to enhance mutual trust and security, but we cannot rule out, over the 2020-2050 timescale, a major shift in the international security situation which puts us under threat.

Emerging Nuclear States

3-10. Over the next 20 to 50 years, one or more states could also emerge that possess a more limited nuclear capability, but one that poses a grave threat to our vital interests. We must not allow such states to threaten our national security or to deter us and the international community from taking the action required to maintain regional and global security. The UK's continued possession of a nuclear deterrent provides an assurance that we cannot be subjected in future to nuclear blackmail or a level of threat which would put at risk our vital interests or fundamentally constrain our foreign and security policy options.

State-Sponsored Terrorism

3-11. We know that international terrorists are trying to acquire radiological weapons. In future, there are risks that they may try to aquire nuclear weapons. While our nuclear deterrent is not designed to deter non-state actors, it should influence the decision-making of any state that might consider transferring nuclear weapons or nuclear technology to terrorists. We make no distinction between the means by which a state might choose to deliver a nuclear warhead, whether, for example, by missile or sponsored terrorism. Any state that we can hold responsible for assisting a nuclear attack on our vital interests can expect that this would lead to a proportionate response.

3-12. A key element of our ability to exercise effective deterrence in such circumstances is our capability precisely to determine the source of material employed in any nuclear device. We will retain and strengthen the world-leading forensic capability at the Atomic Weapons Establishment, Aldermaston in this area. We will also continue to work to strengthen international expertise in this field.

Conclusions

3-13. In view of the continued existence of large nuclear arsenals, the possibility of further proliferation of nuclear weapons in combination with the risk of increased international instability and tension, we believe that a nuclear deterrent is likely to remain an important element of our national security in the 2020s and beyond. We have therefore decided to make the minimum investment required to sustain this capability over that period. We judge that this continues to be a price worth paying.

ANNEX 26 – House of Commons Defence Committee, *The Future of the UK's Nuclear Deterrent: the White Paper*, Ninth Report of Session 2006-07 Vol. I
http://www.publications.parliament.uk/pa/cm200607/cmselect/cmdfence/225/225i.pdf

Costs and funding

Table 8: The costs of renewing the deterrent

Cost item	The Government's cost estimate
Vanguard-class 5 year life extension	"hundreds of millions"
Overall procurement costs	£15-20 billion
Of which: submarines	£11-14 billion
Warhead refurbishment/replacement	£ 2-3 billion
Submarine infrastructure	£ 2-3 billion
In-Service costs (capital and running costs)	£1.5 billion a year
Decommissioning costs	
Nuclear submarines (both SSNs and SSBNs)	£837 million
Shore infrastructure	[unclear – MoD total nuclear liabilities accounted for at £9.75 billion]
Trident D5 missile life extension programme	£250 million
New missile	[unknown – Trident D5 cost £1.5 billion]

139. The costs of renewing the UK's strategic nuclear deterrent reflect the costs of: extending the life of the current Vanguard-class submarine; designing and manufacturing a replacement SSBN; participating in the US Trident D5 missile life extension programme; participating in a future Trident D5 replacement programme; and, refurbishing or replacing the UK's nuclear warheads. There will also be costs associated with the maintenance of onshore infrastructure and of decommissioning retired submarines and warheads as well as the personnel costs of operating the system and its supporting infrastructure.

140. The White Paper estimates that "once the new fleet of SSBNs comes into service, we expect that the in-service costs of the UK's nuclear deterrent, which will include AWE's costs, will be similar to today (around 5-6% of the defence budget)".[188] It also pledges that "the investment required to maintain our deterrent will not come at the expense of the conventional capabilities our armed forces need".[189]

188 Cm 6994, para 5.14, p 27

189 Ibid.

ANNEX 27 – Hansard, HL, 7 June 2010, col. WA28, http://www.publications.parliament.uk/pa/ld201011/ldhansrd/text/100607w0004.htm#10060710000742.

7 Jun 2010 : Column WA28

Asked by ***Lord Luce***

To ask Her Majesty's Government what discussions they have had with the African Union about the Union's policy on the recognition of Somaliland as an independent state; and what was the outcome of these discussions.[HL74]

Lord Howell of Guildford: The Government have not had any discussions with the African Union regarding the recognition of Somaliland as an independent state.

Asked by ***Lord Luce***

To ask Her Majesty's Government whether they are sending observers to witness the presidential election in Somaliland in June.[HL75]

Lord Howell of Guildford: The Government are not sending observers to witness the presidential elections in Somaliland. However, we are engaged with a UK non-governmental organisation that is leading on the co-ordination of international observers. We will continue to work closely with them both before and after the elections in June. The Government will continue to support actively the staging of democratic elections.

Asked by ***Lord Luce***

To ask Her Majesty's Government whether they will recognise Somaliland as an independent sovereign state if the presidential election in June is free and fair.[HL76]

Lord Howell of Guildford: Recognition of Somaliland as an independent state is not connected to the holding of free and fair presidential elections. However, the Government will continue to support actively the staging of democratic elections.

Free and fair elections in June can only strengthen the reputation of Somaliland in the international community.

The criteria applied by the UK for recognition of a state remain as described in the Written Answer dated 16 November 1989 (*Official Report*, col. 494) by the then Parliamentary Under-Secretary of State for Foreign and Commonwealth Affairs.

Trident

Question

Asked by ***Lord Trefgarne***

To ask Her Majesty's Government what is the annual cost of maintaining the Trident submarine fleet, including missiles.[HL103]

The Parliamentary Under-Secretary of State, Ministry of Defence (Lord Astor of Hever): Annual expenditure for capital and running costs of the nuclear deterrent, which includes the Trident D5 missiles, is around 5 to 6 per cent of the defence budget.

ANNEX 28 – HC, 20 December 2012, col. 908W,
http://www.publications.parliament.uk/pa/cm201213/cmhansrd/cm121220/text/121220w0002.htm#12122061000114

Trident replacement design programme. [133492]

Mr Dunne: No BAE Systems employees have been seconded to the Ministry of Defence to work on the Successor Submarine Programme.

One Babcock Marine full-time and two part-time employees and one Rolls- Royce employee have been seconded to work on the programme.

John Woodcock: To ask the Secretary of State for Defence what estimate he has made of the cost of operation of a continuous at-sea deterrent replacement system over the likely lifespan of such a system. [133833]

Mr Dunne *[holding answer 18 December 2012]:* As stated in the White Paper, The Future of the United Kingdom's Nuclear Deterrent (Cm 6994) published in December 2006, we expect that once the new successor

20 Dec 2012 : Column 908W

nuclear deterrent submarine comes into service the in-service costs of the UK's nuclear deterrent, which will include Atomic Weapons Establishment's costs, will be similar to today (around 5% to 6% of the defence budget).

John Woodcock: To ask the Secretary of State for Defence what his most recent estimate is for the cost of design and build for a replacement continuous at-sea nuclear deterrent system. [133834]

Mr Dunne *[holding answer 18 December 2012]:* Current forecast costs, including planned Submarine Enterprise Performance Programme efficiency measures, indicate that we remain within the 2006 White Paper estimates of £11 billion to £14 billion (at 2006-07 prices) for the Successor platform costs (assuming a four boat fleet).

Trident Missiles

ANNEX 29 – Public Expenditure Statistical Analysis 2011, Departmental Budgets, HM Treasury, table 1.3a, available at http://www.hm-treasury.gov.uk/d/pesa_2011_chapter1.pdf

Table 1.3a Resource DEL less depreciation(1), 2006-07 to 2014-15

£ million

	National Statistics								
	2006-07 outturn	2007-08 outturn	2008-09 outturn	2009-10 outturn	2010-11 outturn	2011-12 plans	2012-13 plans	2013-14 plans	2014-15 plans
Resource DEL less depreciation by departmental group									
Education	42,092	44,903	46,819	49,575	51,424	51,463	52,538	53,072	54,008
NHS (Health)(2)	75,899	81,838	88,023	94,611	97,785	101,625	104,092	107,032	109,884
Personal Social Services (Health)	1,730	1,767	1,275	1,393	1,522	0	0	0	0
Transport	6,008	6,099	5,405	5,709	5,170	5,294	5,027	4,965	4,431
CLG Communities	3,326	3,927	4,058	4,275	3,632	2,014	1,784	1,630	1,243
CLG Local Government	22,540	22,750	24,650	25,515	25,956	26,000	23,974	24,198	22,850
Business, Innovation and Skills	14,669	15,863	16,540	17,530	17,229	16,717	15,815	14,844	13,809
Home Office	8,499	8,706	9,013	9,340	8,865	8,987	8,580	8,137	7,864
Justice	7,889	8,526	8,683	8,561	8,620	8,314	7,806	7,437	7,119
Law Officers' Departments	687	705	712	697	658	644	614	590	552
Defence	23,520	24,613	25,403	27,596	27,966	27,413	25,266	24,957	24,746
Foreign and Commonwealth Office	1,639	1,735	1,946	2,022	2,097	2,022	1,463	1,429	1,367
International Development	4,098	4,449	4,742	5,234	5,915	6,465	7,195	9,394	9,412
Energy and Climate Change	911	672	288	1,215	1,148	1,563	1,398	1,341	1,036
Environment, Food and Rural Affairs	2,259	2,356	2,219	2,260	2,166	2,107	2,059	1,913	1,792
Culture, Media and Sport	1,356	1,398	1,435	1,391	1,420	1,448	2,002	1,226	1,131
Work and Pensions	7,611	7,866	7,758	8,547	8,684	7,561	7,377	7,421	7,605
Scotland	21,475	22,905	23,552	24,486	25,224	24,849	25,152	25,344	25,451
Wales	11,366	11,955	12,420	13,074	13,386	13,355	13,367	13,510	13,545
Northern Ireland	8,131	8,635	8,952	9,335	9,637	9,455	9,452	9,511	9,552
Chancellor's Departments	4,441	4,246	4,312	4,226	3,927	3,949	3,820	3,765	3,589
Cabinet Office	1,524	1,621	1,794	1,985	2,029	2,103	2,040	1,964	2,156
Independent Bodies	630	661	746	760	706	862	752	735	719
Reserve	0	0	0	0	0	2,000	2,500	2,600	2,500
Special Reserve	0	0	0	0	0	100	3,100	3,000	2,800
OBR Allowance for Shortfall	0	0	0	0	0	0	0	1,000	0
Total Resource DEL less depreciation	**272,403**	**288,197**	**300,754**	**319,337**	**325,165**	**326,300**	**327,100**	**331,000**	**328,900**

(1) As part of the Spending Review 2010 DEL was presented less depreciation. This is continued in this table to allow comparison.

(2) NHS (Health) includes Food Standards Agency, see Annex B.

ANNEX 30 – *UK nuclear weapons R&D spending: Addendum AA1 to Offensive Insecurity*, February 2014, available at http://www.sgr.org.uk/publications/uk-nuclear-weapons-rd-spending

Addendum AA1. UK nuclear weapons R&D spending

Stuart Parkinson, Scientists for Global Responsibility (SGR); February 2014

Summary

In this addendum to the SGR report, *Offensive Insecurity* (September 2013), we present an estimate of total UK government spending on nuclear weapons R&D, drawing on the data obtained for the report via freedom of information requests, and on further publicly available information about the different R&D spending streams.

The analysis reveals that the UK spent an average of £327m per year over the three years from 2008 to 2011. This included £106m/y on R&D related to Trident nuclear warheads, £127m/y on R&D for new 'successor' submarines to carry Britain's nuclear weapons, and £94m/y on R&D for a new nuclear propulsion system for these submarines.

We also compare the total annual spending on nuclear weapons with other areas of UK public spending on security-related R&D over this period, including those that help to tackle drivers of current and future conflict, such as climate change. One notable comparison is that UK public R&D spending for nuclear weapons technologies was more than five times that on renewable energy technologies during this period.

AA1.1. Analysis of data

A breakdown of the R&D spending data relevant to nuclear weapons – obtained via freedom of information requests to the MoD for the three-year period 2008-11, and summarised in the main report – is given in tables AA1.1-1.3. (The data provided here for 'Long-range submarines' is a more detailed breakdown than that given in appendix A3 to the report.)

There are two key areas of ambiguity in the spending figures: 'Long-range submarines' and 'Nuclear propulsion'. As discussed in chapter four of the main report, the R&D programme for both these areas seems to include work on both conventionally armed and nuclear-armed submarines.

***Table AA1.1. MoD R&D spending programmes relevant to nuclear weapons, 2008-09** (MoD, 2012; 2012b) (cash terms)*

Name	*Abbreviations*	*Code*	*Spending (£m)*
Long-range submarines (nuclear and conventionally armed)	Future Submarines/ FSM IPT/ Strategic Options Group	8367	74.3
	Sub-IPT	8086	1.3
	IPT-Torpedoes	8095	1.9
	UWS / Underwater Warfare Systems	6321	0.0
	IPT-Astute	8140	0.5
Nuclear propulsion (for submarines)	Nuclear propulsion	8151	65.6
Nuclear weapons (warheads)	na	na	104.0

ANNEX 31 – Ministry of Defence (2011) *Initial Gate Parliamentary Report* (London: Ministry of Defence),
https://www.google.nl/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&ved=0CCEQFjAA&url=https%3A%2F%2Fwww.gov.uk%2Fgovernment%2Fuploads%2Fsystem%2Fuploads%2Fattachment_data%2Ffile%2F27399%2Fsubmarine_initial_gate.pdf&ei=bD4BVZnWOYb7PMCOgdgB&usg=AFQjCNHLD_OML9ovvtYhgZu4_Hxt7H6-6g&sig2=9DdXQijRIKRUXK8S31-oBw&bvm=bv.87920726,d.ZWU

6. Cost Estimates

6.1 Submarine Costs

The 2006 White Paper estimated that the cost of the successor deterrent system would be £15-20Bn (at 2006/7 prices) of which £11-14Bn would be attributed to the cost of the replacement platform. These estimates were stated at 2006/7 prices to provide an understandable way of explaining the cost of the replacement deterrent at a constant price base. MOD investment approval is normally made at outturn prices i.e. the sum of the expected spend in each year including inflation and the figures provided earlier in the report are made on that basis. However, expressing costs at 2006/7 prices remains an important way of demonstrating how we are performing and we will continue to provide comparisons against the White Paper estimate. This equates to £25Bn at outturn prices for the successor submarines.

Our assessment is that, assuming a four boat fleet, the replacement submarines will remain within the £11-14Bn estimate. Further work needs to be done between now and Main Gate to refine this estimate, particularly on the benefits to be achieved through SEPP.

This estimate includes programme risk. The MOD and industry operate a joint risk management approach and have developed comprehensive risk registers using the combined experience of Government and industry. This has drawn on the experience from other similar programmes such as Astute and has ensured that lessons identified in those programmes are incorporated into the Successor Programme.

6.2 Wider Programme Costs

Work on the Trident replacement programme has so far concentrated on the submarine. The SDSR concluded that it would be possible to defer decisions on the replacement of both the warhead and infrastructure elements of the programme with a consequential deferral of spend over the next ten years. Over the next few years concept studies will begin to refine potential programmes and costs. In particular we expect that it may be possible to reduce the cost of supporting infrastructure but at this stage the estimates given in the 2006 White Paper of £2-3Bn for each of the two elements stand.

ANNEX 32 – Hansard, HC Deb, 14 March 2007, cols. 298-407, http://www.publications.parliament.uk/pa/cm200607/cmhansrd/cm070314/debtext/70314-0004.htm#07031475000005

That this House supports the Government's decisions, as set out in the White Paper The Future of the United Kingdom's Nuclear Deterrent (Cm 6994), to take the steps necessary to maintain the UK's minimum strategic nuclear deterrent beyond the life of the existing system and to take further steps towards meeting the UK's disarmament responsibilities under Article VI of the Non-Proliferation Treaty.

I must at once declare a potential interest, in that the propulsion system for the existing submarines is manufactured in my constituency.

Let me set out the nature of the decisions that the House is being asked to support today. They are whether or not to take the steps necessary to maintain a minimum strategic nuclear deterrent for the UK—a single system comprising submarines, missiles and warheads—and to take further steps towards meeting our disarmament responsibilities under article VI of the non-proliferation treaty.

Specifically, that will mean a decision to begin a process to design, build and commission submarines to replace the existing Vanguard-class boats. This will necessarily take some 17 years. That is a calculation based on our own experience and that of other allied nuclear weapon states. Moreover, we must also decide whether we will join the American programme to extend to the early 2040s the life of the Trident D5 ballistic missiles which those Vanguard submarines currently carry, and whether we will reduce the number of our operationally available warheads to fewer than 160 by the end of this year.

Mr. Gordon Prentice (Pendle) (Lab): The United States nuclear posture review that went to Congress in December 2001 estimated that it would take 13 years, not 17 years, to replace a US Trident submarine.

14 Mar 2007 : Column 299

Margaret Beckett: The United States submarines are different from our own. They are differently designed, they have a different design life and so on. That may have been the conclusion of American work; it is not the conclusion of the work that has been done in this country.

Dr. Nick Palmer (Broxtowe) (Lab): Does the Secretary of State accept that all these issues must be subject to review over the years, and

ANNEX 33 – Briefings on Nuclear Security, 'Trident: The Initial Gate Decision', http://www.britishpugwash.org/documents/Briefing%203%20-%20Initial%20Gate.pdf

Briefings on Nuclear Security

Trident: The Initial Gate Decision

This third briefing on Nuclear Security focuses on the Government's announcement of the passing of the Initial Gate decision for the Trident renewal project on 18 May, 2011.

What is the 'Initial Gate' decision?

On March 14, 2007 Parliament voted to authorise the initial 'Concept' phase of the Trident replacement system.[1] The next major milestone, known as the 'Initial Gate' decision, was to move to the 'Assessment' phase, involving further detailed refinement of a set of design options to enable selection of a preferred solution. The government announced the Initial Gate decision on May 18, 2011. The next big decision to move to the 'Demonstration and Manufacture' phase is the 'Main Gate' decision, now scheduled for 2016 (delayed from 2014 in October 2010). That is supposed to be the key decision-point when the finalised submarine design is adopted; contracts to build the new boats are then tendered, and billions more pounds will be irrevocably committed to construction of a new generation of nuclear weapons.

Cost

The Initial Gate report puts the cost of replacing the Trident system (including submarines, warheads, infrastructure, and missiles) at £25 billion at outturn prices (prices when projected expenditure actually occurs).[2] Critics, however, point out that the Ministry of Defence (MoD) has struggled to bring in major equipment projects on time and to budget and suggest a procurement figure closer to £30-£35 billion.[3]

The Initial Gate report gave updated figures for spending on the project, revealing that to date, the Concept phase has consumed almost £1billion, and predicting that the Assessment phase authorised by the Initial Gate decision will consume a further £3 billion over the next five years.[4] By the time the Main Gate decision is reached in 2016, approximately 15% of total programme costs will have been spent, including around £500 million on long-lead items for the submarine hulls, reactor and propulsion systems, and combat systems.

This spending coincides with a major funding shortfall in the MoD's future equipment budget of up to £36 billion over the next 10 years. Its budget is being cut by 7.5% over the current Parliament under the 2010 Comprehensive Spending Review, which follows on from the major cutbacks announced in December 2008 and December 2009. The 2010 Strategic Defence and Security Review (SDSR) made a number of difficult decisions to cut the equipment budget, including retiring the Nimrod and Harrier fleets. The MoD are currently undertaking a new three-month study, reporting in July 2011, to consider how even more personnel and equipment programmes could be axed to save several more billion.[5]

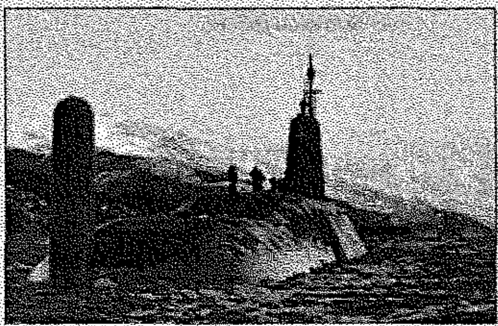
In 2006 Prime Minister Tony Blair stated explicitly that the Trident replacement programme would "not be at the expense of the conventional capabilities that our armed forces need".[6] Greeted with some scepticism at the time, that commitment now appears untenable. Following the announcement in July 2010 by Chancellor George Osborne that the MoD will have to fund

ANNEX 34 – "The United Kingdom's Future Nuclear Deterrent: The Submarine Initial Gate Parliamentary Report" (May 2011), https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/27399/submarine_initial_gate.pdf

3. Progress on the Submarine Programme

3.1 Initial Gate Decisions

The programme to replace the nuclear deterrent is one of the largest and most complex the MOD has undertaken. The Department has completed the initial phase of concept analysis, which addressed the technical issues associated with potential designs and set out the work that will be required in the next phase, known as the Assessment Phase. The key areas covered were:



- **The Submarine Design.** A nuclear-powered attack submarine (SSN) such as the Astute Class is designed to be manoeuvrable and fast. In comparison, nuclear-powered ballistic missile submarines (known as SSBNs) housing missiles over 13 metres in length have historically been around twice the size of attack submarines. Nonetheless there are similarities between the different classes of submarine and a number of systems from the Astute Class design have been incorporated within the design of the successor submarine. This 'pull through' of proven technology reduces costs as well as design and delivery risk for the successor deterrent submarine and ensures commonality in training and maintenance.

  However, we must also be mindful of the opportunities presented by technological developments since the design of Astute and the requirement to sustain the capability throughout the life of the submarine out until the 2060s in order to deliver a design optimised to the unique role of a nuclear-armed submarine. Therefore, we are taking the opportunity to incorporate a new nuclear propulsion design as well as ensuring there is sufficient flexibility and accommodation in the design to deliver through-life upgrades.

- **The Propulsion System.** The Pressurised Water Reactors (PWR) used in submarines work by using nuclear fission to generate heat, which is then used to turn water into steam to turn the main turbines that propel the submarine through the water. There were three PWR options:
  - PWR2 is used in the Vanguard and Astute submarine Classes. It is a safe and reliable design that has served, and will continue to serve, the Royal Navy well but it is based on design features and technology that can now be improved upon;
  - PWR2b is a development of PWR2 seeking to increase PWR2's performance further. However the cost of these improvements is roughly the same as the cost of developing a new design, PWR3; and,
  - PWR3 is a new design that exploits technology that was not available when the Astute design was finalised. Through simpler design it is easier to operate, has a longer in-service life and lower through-life maintenance costs. In addition the introduction of the new design means that it is practicable to implement further improvements to safety.

When considering options a number of factors were taken into account including:

- Capability: The ability of the options to meet the required capability (a 25 year life with the option of at least a five year extension and suitably low detectability);
- Availability: The complexity and maintainability of the propulsion plant (and therefore the submarine);
- Safety: The Health and Safety at Work Act places a legal obligation on MOD Duty Holders and Industry Suppliers to ensure that the risk to the public and employees is reduced As Low As Reasonably Practicable (ALARP);
- Cost: Both in procurement and through-life costs; and,
- Schedule: The confidence of delivering the option to the required timeline.

After careful consideration PWR3 was chosen. PWR3 provides superior performance over PWR2. In availability terms the simplicity of PWR3 and the application of modern design practices and newly matured technology will significantly reduce periods in upkeep and maintenance. A particularly important issue was safety. Nuclear propulsion plants are extremely safe and our nuclear systems are assessed by the Defence Nuclear Safety Regulator to ensure this remains the case. However, this is a new design of submarine and under Health and Safety legislation we are required to look at whether performance can be improved even further. In this case PWR3 offers improvements over PWR2. That does not mean that current systems are unsafe. All our propulsion plants meet the stringent safety standards that have been set by the Defence Nuclear Safety Regulator, but as we move to a new class of submarine the requirement to continually improve our performance and to meet 'ALARP' is only met through PWR3.

In terms of cost, submarines with PWR3 are around £50 Million per boat more expensive to buy and operate over designs incorporating PWR2 over a 25 year life but would be cheaper if we were to operate the deterrent submarines for longer because of PWR3's longer life. We judge that this investment is worth making given the performance and wider benefits offered by PWR3.

ANNEX 35 – Hansard, HC Deb, 18 May 2011, col. 352, http://www.publications.parliament.uk/pa/cm201011/cmhansrd/cm110518/debtext/110518-0001.htm#11051871001523

18 May 2011 : Column 352

the case for alternatives. As Secretary of State for Defence, I am absolutely clear that a minimum nuclear deterrent based on the Trident missile delivery system and continuous at-sea deterrence is right for the United Kingdom and that it should be maintained, and that remains Government policy; but to assist the Liberal Democrats in making the case for alternatives, I am also announcing today the initiation of a study to review the costs, feasibility and credibility of alternative systems and postures. The study will be led by Cabinet Office officials overseen by the Minister for the Armed Forces. A copy of the terms of reference of the study will be placed in the House of Commons Library.

As I have said, the Government have approved the initial gate for the nuclear deterrent successor programme. We have now agreed the broad outline design of the submarine, made some of the design choices—including the propulsion system and the common US-UK missile compartment—and the programme of work we need to start building the first submarine after 2016. We have also agreed the amount of material and parts we will need to buy in advance of the

main investment decision.

We expect the next phase of work to cost in the region of £3 billion. That is a significant sum, but I am confident that it represents value for money for the taxpayer, as every aspect of the programme has been carefully reviewed by MOD, Treasury and Cabinet Office officials. It will fund the programme that we need to conduct to make sure that we can bring the submarines into service on time. Overall, we assess that the submarine element of the programme will still cost within the £11 billion to £14 billion estimate set out in the 2006 White Paper, but these costs were estimated at 2006 prices, of course, and did not account for inflation. The equivalent sum today is £20 billion to £25 billion at out-turn, but it is important to recognise that there has been no cost growth in the programme since the House first considered the findings of the White Paper.

Between now and main gate we expect to spend about 15% of the total value of the programme. That is entirely consistent with defence procurement guidance. The cost of long lead items is expected to amount to about £500 million, but it is not true to say that large parts of the build programme will have been completed by main gate. Although we are ordering some of the specialist components, that does not mean that we are locked into any particular strategy before main gate in 2016.

ANNEX 36 – http://www.number10.gov.uk/news/uk-france-summit-press-conference/

Second, we will cooperate on aircraft carriers. The last government ordered carriers that would be unable to work effectively with either of our key defence partners, France or the United States. This was madness. As a result of the decisions we have taken, we will adapt our new carrier capability so we're able to operate with France and the United States. And as our new carrier comes into service towards the end of this decade, we will develop the ability to deploy a UK-French integrated carrier strike group, ensuring that either a British or a French carrier is always available for operations.

Third, we will work together on equipment and capabilities. We are both procuring the A400M military transport aircraft and will integrate our logistical support for that aircraft. We will work together on the next generation of unmanned aerial vehicles. We will work together on technology for cyber security.

And fourth, while we will always retain an independent nuclear deterrent, it is right that we look for efficiencies in the infrastructure required to develop and sustain our separate deterrents. So rather than both countries building identical and expensive facilities to ensure the safety of our nuclear weapons, we will build together a joint facility, jointly owned and jointly managed, sharing our knowledge and expertise and saving millions of pounds.

Britain and France have a shared history through two World Wars. Our brave troops are fighting together every day in Afghanistan. But let me finish by saying this is a Treaty based on pragmatism not just sentiment and I would like to thank Nicolas for joining me in taking these bold and important steps, which I believe will make our sovereign nations safer.

Thank you, Nicolas.

ANNEX 37 – http://www.reachingcriticalwill.org/images/documents/Disarmament-fora/npt/prepcom12/statements/30April_UK.pdf

5. The UK wants to bridge the perceived divides and help to build a shared understanding of what we can all gain from the NPT. The shared success of 2010 showed that we are moving in the right direction; the UK believes that we must continue to build on that positive momentum, right the way through to the RevCon in 2015.

1. 2011 was the so-called 'fallow year' in the cycle, and yet we saw the second P5 Conference in Paris, agreement by the P5 and ASEAN on the P5 Protocol to the South East Asia Nuclear Weapon Free Zone, which we will discuss in greater detail over the next two weeks, promising steps forward on the Middle East WMD Free Zone Conference, and a momentous report from the IAEA on the military dimensions of Iran's nuclear programme.

7. This Preparatory Committee has a strong procedural remit, being the first in the review cycle, but we must also look to build on the consensus from 2010, and the positive developments that we saw in 2011. The UK sees this first PrepCom as an opportunity for state parties to collectively reaffirm their unconditional support for the NPT and their commitment to action plan implementation.

Disarmament

8. As a nuclear weapon state, the United Kingdom is fully aware that it has particular responsibilities to fulfil. The UK remains fully committed to the long-term goal of a world without nuclear weapons and we believe that we have a strong track record in meeting our disarmament commitments and obligations under the NPT.

9. As long as large arsenals of nuclear weapons remain and the risk of nuclear proliferation continues, the UK's judgement is that only a credible nuclear capability can provide the necessary ultimate guarantee to our national security. The UK Government is therefore committed to maintaining a minimum national nuclear deterrent, and to proceeding with the renewal of Trident and the submarine replacement programme.

10. We have taken a number of additional important disarmament steps during and since the 2010 Review Conference, and we will give further detail of these measures in our statement under Pillar I. But, in general terms, these important confidence building measures include increasing the UK's transparency by announcing for the first time the overall size of our warhead stockpile and publishing the most detailed Security and Defence Review in our history, reducing the number of warheads on our submarines, reducing our nuclear weapon stockpile and drawing up an updated negative security assurance to non-nuclear weapon states. We have already started the implementation of these measures, and have started to reduce our warhead numbers 15 years ahead of schedule.

11. We also continue to work closely with our P5 partners on implementation of the NPT Action Plan. Co-operation within the P5 has come a long way. Let us not forget that at the height of the Cold War, which many of us in this room can remember well, these same states that now meet recurrently to talk about disarmament confidence

ANNEX 38 – http://www.reachingcriticalwill.org/images/documents/Disarmament-fora/cd/2013/Statements/5March_UK.pdf

Madam President

The United Kingdom aligns itself with the intervention just delivered on behalf of the European Union.

Nuclear disarmament is a very important topic for the United Kingdom and the Conference on Disarmament is the pre-eminent forum in which the international community addresses nuclear disarmament, so there is much to say. In the interests of time, I will circulate the entire speech but summarise the key points orally.

The United Kingdom has long been committed to the goal of a world without nuclear weapons. We continue to play an active role in helping to build an international environment in which no state feels the need to possess nuclear weapons. Sadly, we are not there yet. There are still substantial nuclear arsenals, the number of nuclear-armed states has increased rather than decreased, and there is a significant risk of new nuclear-armed states emerging. Several countries that either have nuclear weapons or are trying to acquire them are in regions that suffer from serious instability or are subject to significant regional tensions, so there is still the potential for a new nuclear threat to emerge despite the end of the Cold War.

While there continue to be significant risks of further proliferation and while other states retain much larger nuclear weapons arsenals, we have been clear that the United Kingdom will retain a minimum credible nuclear deterrent as the ultimate guarantee of our security.

In 2007, the United Kingdom Parliament debated, and approved by a clear majority, the decision to continue with the programme to renew the UK's nuclear deterrent. The Government set out in the 2010 strategic defence and security review that the UK would maintain a continuous submarine-based deterrent and begin the work of replacing its existing submarines which are due to leave service in the 2020s. This remains the UK Government's policy.

A study known as the *Trident Alternatives Study* is ongoing and is due to report to the UK Prime Minister and Deputy Prime Minister in the first half of 2013. It is too early to speculate about the conclusions of *The Trident Alternatives Study*. An unclassified document on the *Trident Alternatives Study* will be published in due course.

Madam President

This then is our policy on our nuclear deterrent. Let me speak now about disarmament. People sometimes ask the United Kingdom to take action to match our words. The record shows that we have already taken significant actions. We have moved from living in a world of tens of thousands of nuclear warheads, standing to fire at a moment's notice during the Cold War, to a world in which the major nuclear weapons states have significantly reduced their arsenals, have stopped targeting them at anyone and have reduced their operational readiness. More recently, in 2010 we saw the signing of the new START agreement between the United States and Russia, holders of the largest nuclear stockpiles by far. Under that treaty, both countries agreed to reduce the number of strategic nuclear missile launchers by half and to limit the number of deployed strategic nuclear warheads to a figure nearly two-thirds lower than that agreed in 1991.

In the same year, we saw the agreement of the first ever Nuclear Non-Proliferation Treaty action plan, in which all 189 signatories reaffirmed their commitment to the treaty and committed to making tangible progress towards our shared goal of a world without nuclear weapons. Under that plan, nuclear weapons states all committed to making concrete progress on the steps leading to nuclear disarmament, including reducing the overall global stockpile and reducing further the role and significance of nuclear weapons in our military doctrines. Next year – at the third NPT Preparatory Committee in New York, we will set out publicly how we have made progress on this action plan.

Madam President.

The UK's own record on nuclear disarmament is strong.

ANNEX 39 – http://www.basicint.org/sites/default/files/ingramcommentary-tar-jul2013.pdf

BASIC British American Security Information Council

Paul Ingram,
BASIC Executive Director
16 July 2013

Commentary on the UK Trident Alternatives Review

The government published its Trident Alternatives Review earlier today. This short briefing gives an immediate response. BASIC will later this year be publishing the results of the Trident Commission, considering the broader issues that form the context of the decision.

Today's technical government review has highly political roots in the desire by Liberal Democrats to ask two key (strategic, political) questions:

i) are there cheaper options that maintain a credible minimum nuclear deterrent capability appropriate to the changed circumstances of the 21st century?

ii) are there options that offer greater flexibility to enable Britain to respond to future developments in the strategic environment, and to enable Britain to have credible negotiating positions at any future multilateral disarmament talks.

Danny Alexander, speaking at RUSI on the report at lunchtime today, said that the report supported his view there was a credible alternative involving the construction of three submarines and what he called a high readiness focused deterrence posture, retaining the ability to return to continuous patrols in time of crisis but not otherwise requiring continuous patrolling. He said that this would realise savings in cash terms of some £4 billion, much of which would land in the late 2020s.

The Review is an important contribution to the public debate in that it presents more information in the public domain than ever on the options and demonstrates healthy divisions at the heart of government. However, the review has a number of limitations in its scope and in the assumptions made. It does not address:

i) Non-nuclear options, and the more basic question: should Britain have nuclear weapons in the 21st century?

ii) The evolving nature of the security context for the question of whether nuclear deterrence has relevance, and also therefore one must question whether it can adequately answer the question of what a minimum deterrent could be.

iii) The opportunity costs – the choices foregone and impacts on security because of investments ploughed into nuclear weapons investments.

iv) The international politics surrounding nuclear non-proliferation, and the opportunities Britain has to influence other states and achieve progress under the non-proliferation regime.

Equally importantly, the review contains within it key assumptions. It defines a minimum deterrent, that whilst not fully attached to a Continuous at-sea deterrent (CASD) posture, is nevertheless close to it – the independent capability, "to deliver at short notice a nuclear strike against a range of targets at an appropriate scale and with very high confidence", and to maintain this capability for an extended period. This is a tough requirement, and rules out significant further reductions in patrols and readiness, and some dual-capable options that could otherwise prove attractive. But how necessary is this requirement in a world where the government assesses the probability of the emergence of a strategic nuclear state-based threat to be very low, and where we have strong and healthy alliance relationships?

The UK places NATO at the heart of its national security, and allocates its nuclear capability to Alliance operations. This requirement for independent operation, one that Danny Alexander admitted was a core assumption in answer to a question from me at RUSI earlier today, shows little faith in the long term health and capabilities of the Alliance, and sends the rather strong message internationally that in the last analysis Britain, the country politically and strategically closest to the most powerful state in the world, does not have faith in its bilateral or multilateral alliance relationships. What does this do for confidence in international regimes, and for the UK's non-proliferation policy?

If Britain does not yet have the confidence in the international security situation to give up nuclear weapons entirely, or feels somehow that it has responsibilities to its NATO allies to shoulder the nuclear burden with the Americans and French, then it could more unambiguously pool those assets with its NATO partners, and ensure a solid and reliable continuous at-sea deterrence. This would realise substantial savings that blow those mentioned in the TAR out of the water.

Why do we have to cling onto the expensive fig leaf that the British nuclear system is operationally independent, when we know that there are no politically credible scenarios when the UK would be firing its nuclear weapons against the wishes of the Americans? Those keen to resist reductions have jumped on any suggestion of reducing patrols as creating a 'part-time deterrent'. But isn't that exactly what we need today, something that is flexible and appropriate to the threats we face... or are we really saying that the current situation demands a permanent Cold War response? Britain needs to be in a position to offer something on the global table of nuclear disarmament, and this requires a greater level of flexibility than many seem willing to contemplate.

If CASD were dropped in 2016 and the independent operation requirement relaxed, and if the two newer Vanguard submarines were to have their fuel removed and to be mothballed, the life of the current fleet could be extended by perhaps an additional seven years, enabling a number of savings to be realised: delayed and reduced capital spend (only two submarines) and reduced running costs. It would also open up a desirable flexibility in the UK posture, reflecting changed circumstances. This and other similar options were not explored in the TAR report.

Much of the analysis in the report revolves around assumptions behind the length of time it would take the UK to develop a new warhead for the Trident missile (17 years) and a new warhead for any new delivery system like a cruise missile (an additional 7 years on top). These lead-times appear to rule out many alternative options on that basis that there is insufficient time to develop the warhead for those alternatives, before the current submarines reach the end of their useful life around 2030.

If the nuclear deterrent really is the national asset that many claim, these lead-times could surely be reduced significantly. They compare unfavourably with the widespread estimates of Iran's capabilities to field a nuclear weapon in months from scratch and without allies. The Americans have shared much of their Trident warhead specifications with us, are they really unwilling to share the development of their future air-launched cruise missile warheads with us?

Today's review will inform the final deliberations of the Commission, and both documents should play an important role in the forthcoming debate over the future of Trident.

ENDS

ANNEX 40 – T. Fenwick, "Retiring Trident: an alternative proposal for UK nuclear deterrence", *CentreForum,* (2015), http://www.centreforum.org/assets/pubs/retiring-trident.pdf

3 - Critiquing the Trident Alternatives Review

Published in July 2013, the Trident Alternatives Review (TAR) considered a range of alternatives to like-for-like replacement of CASD Trident. These included changes to the warhead and delivery system (i.e. replacing Trident with another nuclear system) and the readiness state (i.e. moving away from a continuous readiness state either with Trident or with another nuclear system).

The most useful element of the TAR is its reconsideration of the "unacceptable loss" notion at the heart of deterrence theory, by accepting that the absolute level of damage to deliver unacceptable loss will vary from adversary to adversary. In doing so, it accepts that the "Moscow Criterion" does not prescribe an absolute level of destructive capability. Further, nuclear weapons are explicitly reserved for nuclear states' targets that cannot be held at risk by UK conventional capabilities. Crucially, this means that deterring non-P5 states' less well-defended targets, a lower level of capability than Trident offers would still provide a sufficient threat that the deterrent effect would be achieved.

Four TAR Analytical Failings

Given that a major reason for considering alternatives to Trident is to reduce the costs, the "Costs" section of the TAR is critical.[139] As published, four analytical failings fundamentally undermine this section of the TAR's analysis.

Free fall costings

First, the JSF / modernised WE.177 free-fall bomb option that is referenced elsewhere in the TAR is excluded from the cost comparator Chart A[140]; the only JSF option shown is for JSF carrying a yet-to-be developed supersonic cruise missile. It is assessed that this curious omission is because a JSF / modernised WE.177 free-fall bomb option would be available before the *Vanguard*-class SSBN out of service date (OSD), meaning

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ANNEX 41 – Hansard, HC Deb, 6 March 2014, cols. 1077-1078, http://www.publications.parliament.uk/pa/cm201314/cmhansrd/cm140306/debtext/1403060002.htm#14030652000003

6 Mar 2014 : Column 1077

Nuclear Submarines

12.22 pm

The Secretary of State for Defence (Mr Philip Hammond): Before I make my statement, I am sure that the House will want to join me in sending condolences to the family and friends of the sapper from 32 Engineer Regiment who sadly died while on duty in Helmand province yesterday as a result of non-battle related injuries sustained in Camp Bastion. The incident is not believed to have involved any enemy action. The serviceman's next of kin have been informed and have requested the customary 24-hour delay before further details are released.

With permission, Mr Speaker, I wish to inform the House that I have decided to refuel the nuclear reactor in HMS Vanguard, one of the UK's four ballistic missile submarines, during its planned deep maintenance period, which begins in 2015. It will be the second time that Vanguard's reactor has been refuelled since it entered service in 1993. I will explain to the House now why I have

reached the decision to conduct a second refuelling.

As many hon. Members will know, alongside the operational reactors on board our ballistic missile submarines, a prototype reactor of the same class has been running at the naval reactor test establishment at Dounreay in Scotland since 2002. Its purpose is to help us assess how the reactor cores within our submarines will perform over time. It has therefore been run for significantly longer periods and at a significantly higher intensity than the cores of the same type in our submarines, to allow us to identify early any age or use-related issues that may arise later in the lives of the operational reactor cores.

In January 2012, low levels of radioactivity were detected in the cooling water surrounding the prototype core. Low levels of radioactivity are a normal product of the nuclear reaction that takes place within the fuel, but they would not normally enter the cooling water. The water is contained within the sealed reactor circuit, and I can reassure the House that there has been no detectable radiation leak from that sealed circuit. The independent Defence Nuclear Safety Regulator and the Scottish Environment Protection Agency have been kept informed.

When the coolant radioactivity was first detected, the reactor was shut down as a precaution. Following investigations and a series of trials, and with the agreement of the relevant regulator, the reactor was restarted in November 2012. It continues to operate safely. Both radiation exposure for workers at the site and discharges from the site have remained well inside the strictly prescribed limits set by the regulators. Indeed, against the International Atomic Energy Agency's measurement scale for nuclear-related events, this issue is classed as level zero, which is described by the agency as

"below scale—no safety significance".

The naval reactor test establishment is, and remains, a very safe and low-risk site. However, the fact that low levels of radioactivity have been detected in the coolant water clearly means that the reactor is not operating exactly as planned. As one would expect, we have conducted extensive investigations to determine how the radioactivity has entered the cooling water. We believe that it is due to a microscopic breach in a small

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detect it straight away.

Despite that, we now have to consider the possibility, however remote, that the useful operating life of this particular design of core may not be as long as previously expected. As a result, I have decided that, as a precautionary measure, we should refuel HMS Vanguard, the oldest SSBN class and the one with the highest mileage, as it were, on her reactor, when she enters her scheduled deep maintenance period in 2015. This is the responsible option: replacing the core on a precautionary basis at the next arising opportunity, rather than waiting to see if the core needs to be replaced at a later date, which would mean returning Vanguard for a period of unscheduled deep maintenance, potentially putting at risk the resilience of our ballistic missile submarine operations.

The refuelling will increase our confidence that Vanguard will be able to operate effectively and safely until the planned fleet of Successor submarines begins to be delivered from 2028. The refuelling will be conducted within the current planned dry dock maintenance period for Vanguard, which starts in late 2015 and will last for about three and a half years. It is therefore expected to have no impact on deterrent operations. The additional cost of refuelling Vanguard is estimated to be about £120 million over the next six years.

A decision on whether to refuel the next oldest submarine, HMS Victorious, when she enters her next planned deep maintenance period does not need to be made until 2018. It will be informed by further analysis of the data from the reactor at Dounreay and examination of the core after the reactor is decommissioned. I have decided, again on a precautionary basis, that in the meantime we will take the necessary steps to keep open the option of refuelling Victorious. That will involve investment at Devonport and at the reactor plant at Raynesway in Derby to preserve our ability to conduct nuclear refuelling. The total cost of that investment is still being scoped, but it is expected to be of the order of £150 million.

Those costs—perhaps £270 million in total—will be met from existing provision for financial risk in the submarine programme budget. They represent substantially less than 10% of that risk provision and will not impact on the more than £4 billion of contingency that we are holding in the overall defence equipment plan.

ANNEX 42 – Hansard, HC Deb, 20 January 2015, col. 183, http://www.publications.parliament.uk/pa/cm201415/cmhansrd/cm150120/debtext/150120-0003.htm

20 Jan 2015 : Column 183

Mr Dunne: Every study that we have looked at so far has said four, so that is where we stand, and I hope that the hon. Gentleman does too.

Finally, I turn to the position advocated by my hon. Friend the Member for North Devon (Sir Nick Harvey), whom we found dancing on the head of a pin in talking about a bizarre new Lib Dem

policy aspiration. Far from a minimum nuclear deterrent capability delivered with a two boat option for dual use, he has developed a new policy on the hoof—not a part-time deterrent but a kit-part deterrent. Apart from the fact that neither of those options was even considered by the alternatives review, this has demonstrated that the Liberal Democrat party is—

Pete Wishart *claimed to move the closure (Standing Order No. 36).*

Question put forthwith, That the Question be now put.

Question agreed to.

Main Question accordingly put.

The House proceeded to a Division.

Mr Speaker: I wonder whether in the light of the delay—it has been 17 minutes thus far—the Serjeant at Arms might investigate the delay in both Lobbies.

The House having divided:

Ayes 35, Noes 364.

ANNEX 43 – Hansard, HC, 20 January 2015, col. 4WS (HCWS210), http://www.publications.parliament.uk/pa/cm201415/cmhansrd/cm150120/wmstext/150120m0001.htm#15012039000001

20 Jan 2015 : Column 4WS

DEFENCE

Nuclear Deterrent

The Secretary of State for Defence (Michael Fallon): As part of his statement on the strategic defence and security review (SDSR) on 19 October 2010, my right hon. Friend the Prime Minister announced that we had reviewed our nuclear deterrence requirements. He concluded that we could deliver a credible nuclear deterrent with a smaller nuclear weapons capability and would incorporate these reductions into the current deployed capability and the future successor deterrent programme. The number of deployed warheads on each submarine would be reduced from 48 to 40; the number of operational missiles in the Vanguard class ballistic missile submarines (SSBN) would be reduced to no more than eight; and we would reduce the number of operationally available warheads from fewer than 160 to no more than 120.

The then Secretary of State for Defence, my right hon. Friend the Member for North Somerset (Liam Fox), announced to the House on 29 June 2011, *Official Report*, columns 50-51WS, that the programme for implementing the 2010 SDSR warhead reductions had commenced.

I am pleased to inform the House that this Government have now met their commitment to