Document Title: The Qualitative Nuclear Arms Race

Author(s): George Lindsey

Date(s): May 1983

Document Type/Physical Description: Type-written, 17pgs

Fonds/Collection Name: George Lindsey Fonds

Series: Nuclear

File/Box Number: 2/1

Original Archival Reference: N/A

Item Description: This document is a typed paper that Lindsey prepared for the Canadian Student Pugwash Conference that took place in Ottawa, Ontario in May 1983.

Keywords: nuclear warheads; delivery methods; range; launch modes; accuracy; ballistic and cruise missiles; size of missiles; land-, sea-, and space-based launch; penetration of defences; active and passive nuclear defences; non-strategic nuclear weapons

THE QUALITATIVE NUCLEAR ARMS RACE

prepared by

G. R. Lindsey

for

Canadian Student Pugwash

Ottawa

May 1983

THE QUALITATIVE NUCLEAR ARMS RACE

THE QUALITATIVE NUCLEAR ARMS RACE

INTRODUCTION

An adequate discussion of the qualitative nuclear "arms race", including consideration of its strategic significance in the 1980s, must go beyond a technical account of the capabilities of the nuclear warheads themselves. It must include the means of delivery, the countermeasures in place and being developed to defend against the weapons, and an assessment of the likely success of offence and of defence.

The term "arms race" suggests a form of zero-sum competition in which one competitor can gain only at the expense of the other(s). While this is a very important aspect of the qualitative developments of nuclear weapons, it is by no means the only one. Improvements to the safety of nuclear weapons, or to their security against theft by terrorists, for example, are likely to be beneficial to the security of both of the major adversaries, and are by no means competitive developments.

However, in this paper, it is the competitive aspects that will be discussed, including means of delivery and means of defence.

THE ENERGY YIELD OF NUCLEAR WARHEADS

There is no "race" to make nuclear warheads with total energy yields that are greater, or smaller, than the extremes that have been achieved already. A three-stage fission-fusion-fission bomb could be designed to yield as many megatons as desired, but the tendency has been to reduce rather than increase the yields of the larger weapons. The largest known explosion was a Soviet test in 1961, releasing 58 megatons, whereas few of the warheads in the inventories of the 1980s have yields much beyond one megaton. At the other end of the scale, sub-kiloton yields can be achieved, although the total size and cost of the warhead does not decrease proportionately with the energy yield. Although there are design problems, the absence of small nuclear weapons with yields equivalent to ten or a hundred tons of TNT is due not so much to the inability to design them as to the lack of a perceived role. In fact, it will be easier to preserve the "firebreak" between conventional and nuclear war if there is a large gap between the energy yields of the largest conventional and the smallest nuclear weapons. We may note that the "Davy Crockett" recoilless rifle, the smallest nuclear weapon in the American arsenal, was withdrawn from service some years ago.

Advances have been made in the ability to determine the form in which the energy is released by a nuclear explosion. A fission reaction releases about 85% of the energy in the form of blast and heat, and about 5% as prompt neutron and gamma radiation. But a thermonuclear fusion reaction of the same total yield releases five or six times as many neutrons, and more gamma rays. By combining a small fission trigger with fusible material, the proportion of energy released in the form of prompt radiation can be increased well beyond what is produced by a small "standard fission" weapon. The resulting Enhanced Radiation/ Reduced Blast Weapon, or "neutron bomb", would be particularly effective on the battlefield for use against tanks, since the armour of a tank (intended for protection against antitank guns and missiles) provides excellent protection against blast and heat, but not against prompt radiation. An additional advantage of the ERW for forces attempting to defend their own towns and cities against tanks is that the blast and heat radiated from the nuclear explosion, nearly useless for destruction of tanks, is the prime cause of destruction of buildings, so that the reduction will reduce unwanted "collateral damage", against buildings and populations.

An objective for any weapon designer is to maximize the "yield-to-weight" ratio, thus providing more destructive capacity for a given payload. Gradual increase in yield-to-weight ratios of nuclear weapons is being achieved.

THE CAPABILITIES TO DELIVER NUCLEAR WARHEADS

Range

There is no longer any technological limitation to the range of nuclear weapons. They can be delivered to any point on the earth's surface.

Launch Modes

Historically, the first means of delivery of strategic nuclear weapons was by unguided bombs, carried and dropped by long-range aircraft. The only two nuclear weapons ever used in war were fission bombs dropped from USAF B-29 bombers over Japan in 1945. Through the 1950s, the bomber was the only means of delivering nuclear weapons. However, by 1960, advances in ballistic missiles, stemming from the wartime German V2, offered the possibility to deliver military payloads to very long ranges, and improvements in the yield-to-weight ratios of nuclear warheads allowed them to be carried by large ballistic missiles or by medium-sized aircraft. Concurrently, extension of the German accomplishments with the wartime V1 allowed nuclear warheads to be mounted on cruise missiles, with ranges adequate for theatre use.

Nuclear weapons can be dropped from aircraft as gravity bombs, or launched from aircraft in the form of ASBMs (air-to-surface ballistic missiles), ALCMs (air-launched cruise missiles), or ASMs (air-to-surface missiles powered by rocket motors for part of their flight). ASBMs were limited by the SALT II treaty, and do not seem to have received much attention since the cancellation of the American Skybolt missile in 1962. However, many versions of air-to-surface missiles were deployed throughout the 1960s and 1970s, and in the 1980s we are seeing development of long-range ALCMs. Any long-range air-to-surface missile reduces the need for the launching aircraft to expose itself to, or to penetrate air defences, and the missile is likely to be a much more difficult target for air defences than the much larger (and probably slower and higher flying) mother aircraft.

The capabilities of ballistic missiles underwent a remarkable development during the 1960s. The land-based versions achieved intercontinental range, the preparation time needed to ready them for launch was drastically reduced, and it became possible to program one missile to be ready for any one of several missions. Similar advances were made for submarine-launched missiles, an even more extraordinary accomplishment when one considers the restrictions of a submarine. Any missile adapted for launch from a submarine can be launched from a large surface ship.

Cruise missiles have received very different attention from East and West. Both took early advantage of the wartime German developments, but Western enthusiasm flagged when the potentialities of ballistic missiles became evident. The USSR persisted with cruise missiles for the navy, and for most purposes succeeded in replacing the large-calibre naval gun by cruise missiles of longer range, able to carry a nuclear or a conventional warhead, and light enough for the smaller (non-nuclear) versions to be mounted in small ships. Antiship missiles, launched from submarines, ships or aircraft, could be provided with homing systems enabling them to find and attack their target. Then, due to an unplanned combination of independent technological advances, the USA returned to the cruise missile as a carrier of nuclear weapons over long as well as intermediate ranges. The relevant technological advances were in propulsion, allowing a small turbofan engine to achieve long range on a small amount of fuel, in guidance, permitting accurate navigation over an evasive route at low altitude, and in the ability to encompass a powerful nuclear warhead within a small lightweight package.

A modern cruise missile is small enough to be launched from a ground launcher that can be mobile or fixed, from an aircraft, from a surface ship, or even from the torpedo tube of a submarine.

Since men or instrumented capsules can be put into earth orbit and subsequently returned to earth close to a predetermined recovery point, there is no doubt that the same thing could be done with nuclear weapons. Placing a nuclear weapon in orbit would break the outer space treaty signed by about ninety countries, and there seems little military reason to do such a thing. An ICBM is less vulnerable than a satellite, and would be able to deliver its nuclear warhead more accurately and without having to wait for the earth to turn into the right position.

Accuracy

The first long range cruise missiles were too inaccurate to be useful as strategic nuclear weapons, and the radio guidance available for the launch phase of the earlier ballistic missiles was only able to deliver the weapon to within a few thousand metres of a target many hundreds of kilometres down range. Inertial guidance offered significant improvement, and now permits Intercontinental Ballistic Missiles to be delivered with accuracies of a few hundred metres. Such accuracy is dependent on careful surveys of the earth's shape, as well as its gravitational field. Further improvements are to be expected from the use of stellar guidance, navigation by means of a satellite system such as NAVSTAR, and terminal guidance that would steer the missile to a feature on the terrain that had been previously mapped.

Cruise missiles will be able to take advantage of all these guidance techniques plus an additional very effective one known as terrain comparison (TERCOM), which is a form of on-course map reading of the contours of the ground, previously recorded by satellites and stored in the computer memory of the missile.

Multiple Warheads

When the yield-to-weight ratio of nuclear warheads reached a certain level, it became possible to fit more than one warhead into a large missile. The mechanics of blast are such that more damage can be done to an extended target such as a large city by several smaller warheads, suitably scattered, than by one larger one with the same total energy. But soon after these "Multiple Reentry Vehicles" were deployed, the art of accurate guidance reached the state that it became possible to guide each of several reentry vehicles to separate aim points. Today the most advanced of the larger missiles carry "Multiple Independently Targetted Reentry Vehicles" (MIRV), enabling one missile to attack a number of separate targets. This development has had extremely significant strategic consequences, since it allows one attacking missile to destroy several opposing missiles, giving an important advantage to the originator of a counterforce attack.

Size of Missiles

A combination of higher yield-to-weight ratios for nuclear warheads with more efficient rocket propulsion and miniaturized guidance and control mechanisms has now permitted many warheads to be placed in one large ballistic missile (the choice made by the Soviet SS-18, for example), or the construction of a small missile able to achieve intercontinental range (the USA is contemplating a very small "Midgetman" ICBM with one warhead). Since MIRVs are at the heart of the new and destabilizing capability to threaten a disarming first strike against ICBMs, it is possible that stability could be restored by a return to small less vulnerable missiles with a single warhead.

Penetration of Defences

Bomber aircraft have to face air defences, including long range early warning radar, interceptor aircraft, surface-to-air missiles, and antiaircraft guns. Recent developments are tending to strengthen the capabilities of air defences, especially against aircraft flying at medium to high altitude. The countermeasures for the bombers are to fly low, reducing the effectiveness of ground based radar, or to equip themselves with air-to-surface missiles (ASM or ALCM) which can be released before the aircraft has to penetrate all of the defences. With a long range ALCM able to navigate accurately at low altitude along an evasive route, the air attack is much more likely to succeed. Another development that will favour the bomber carries the label "stealth", a design technique to reduce the ability of radar to detect and track the aircraft (or possibly also the missile in flight). In addition, there are other penetration aids, such as electronic warfare, decoys to simulate the bomber, and active weapons for defence suppression.

In the absence of serious Ballistic Missile Defence (BMD), ballistic missiles have few problems in penetrating to their targets. Should BMD be deployed on a significant scale, a number of penetration aids are available to the offence, including decoys and chaff, use of nuclear bursts to black out radar detection or to damage electronic components of the defence systems by the electromagnetic pulse, or manoeuvre of the reentry vehicle.

Active defence against ballistic missiles was developed to the stage of actual deployment over ten years ago, but has been limited since then by the ABM treaty of 1972. Detection and tracking depended on large ground-based radar, and interception was carried out by guided missiles armed with nuclear warheads. Research and development has continued, and it is likely that a BMD deployed in this decade would include a tracking system mounted in a high altitude rocket, using infrared radiation to discriminate the warheads from accompanying debris, and quite probable that some of the interceptors would have conventional rather than nuclear warheads. Active BMD of hardened point targets such as missile silos would be much easier than defence of large area targets such as cities, especially since survival of a reasonable fraction of the defended silos would constitute a successful defence, whereas penetration of a small proportion of the warheads attacking cities would represent a defeat for the defence.

Speculation is growing regarding the possibility of destroying ballistic missiles in flight by Directed Energy Beams rather than by interceptor rockets. It appears that High Energy Laser beams are more promising than are Charged Particle Beams, and that the difficulties of projecting the beam through the atmosphere could be overcome by placing the source in an orbiting satellite. However, many very difficult problems of engineering must be overcome before such a system can be made into a practical and economically affordable weapon able to destroy large numbers of intercontinental missiles in flight, and if it were, countermeasures would be available to the missiles.

Active defence against submarine-launched ballistic missiles, or against intermediate or short range land-based ballistic missiles would probably be similar to that for ICBMs, but the shorter warning time and lower trajectory would make the task even more difficult.

MEANS OF DEFENCE AGAINST NUCLEAR ATTACK

Active Defences

The defences against bombers are acquiring new capabilities. Long distance early warning is enhanced by Over-the-Horizon radar, able to detect aircraft far beyond the normal limits of line-of-sight ground-based radar. Both warning and control of interceptors is very much aided by the Airborne Warning and Control System (AWACS), especially against bombers flying at low altitude. For the interceptors to be effective against low altitude bombers, they and their air-to-air weapons need the look-down shoot-down capability now possible with doppler rader.

In coming years it is likely that satellites equipped with special moving target indication radar, or possibly with infrared sensors, will be able to detect aircraft in flight at any altitude, and over a very large area.

While low-flying cruise missiles will be more difficult targets than aircraft, the same combination of detection by AWACS or satellite and engagement by look-down shoot-down interceptors, Surface-to-Air Missiles, and AA guns, may be capable of successful defence, especially if concentrated around particularly valuable targets.

Early warning of the launching and approach of long-range ballistic missiles is now possible with high reliability. The most effective detection systems are based in geosynchronous satellites carrying infrared sensors, and able to report back to earth very quickly as soon as they record the heat from the booster rockets. Tracking of the missiles in mid-course is performed by large ground-based radars.

In the case of the SLBM there is the possibility of attacking the submarine, rather than the missiles in flight. However, the very long range of the latest SLBMs allows the submarine to remain hidden in the ocean at a great distance from its targets, making it extraordinarily difficult to find, at least until it begins to launch its missiles.

Passive Defence

Little can be done to defend cities against destruction by nuclear attack. Shelters can provide effective protection against radioactive fallout for people not too close to "ground zero", but they should be furnished with the means to survive for many days without coming out for more than brief periods. Effective protection against blast, heat, and prompt radiation for persons close to ground zero is more difficult.

For the purposes of deterring, as opposed to surviving, attack it is more important to ensure the survival of a reasonable proportion of the retaliatory weapons. This is practically assured for submarines at sea, and can be arranged for bomber aircraft if they are able to take off in a matter of a few minutes, on receipt of warning of impending attack. But for land-based weapons, the increasing accuracy of the multiple independently targeted reentry vehicles is rendering any fixed target of known location ever more vulnerable. Underground silos buried in reinforced concrete reduce the vulnerability to inaccurate attack, but once the miss distance comes down to a hundred metres or less, a nuclear groundburst is almost sure to destroy the missile in its silo. Something may be gained by placing the missile deep in a tunnel or cave, but the exit is likely to be blocked by rubble. It seems more likely that the best way to ensure the survival of a proportion of the missiles is to have them mobile, and to move them among shelters which will provide concealment and possibly also a degree of physical protection. Even more effective defence may be possible by a combination of mobility with active defence, which could be concentrated on the shelters where the missiles were at the moment of attack.

Plans for the American MX missile, intended to provide an invulnerable deterrent, have gone through several basing modes. One would have had the missiles movable along a "racetrack" between shelters. Another (labelled "Densepack") would have located them close together in hardened silos, in the hope that a salvo of attacking reentry vehicles, arriving nearly simultaneously, would destroy one another by their fratricidal effects. Other ballistic missiles such as the Soviet SS-20 and the American Pershing, and cruise missiles such as the American GLCM, will be road-mobile, but will rely on the natural overhead cover of trees for concealment. The capability to make very small ICBMs will ease the problems of making them mobile. A feature of mobile systems that would pose problems for arms control is the difficulty of verifying the numbers deployed, even if satellite photography could identify weapons while visible on the move.

In addition to the danger of destruction by a nearby nuclear burst, modern weapon systems such as ground-based missiles, including their control units, or the aircraft or ships carrying nuclear weapons, are vulnerable to the effects of the Electromagnetic Pulse (EMP). EMP can be generated by a high altitude nuclear burst, and the effects on sensitive electronic components can extend over a range beyond a thousand kilometres. Means of "hardening" the components and circuits against EMP are being developed, but they are difficult and expensive.

Protection of personnel from the effects of nuclear radiation takes two forms. Comparatively thin layers of certain materials can provide effective shielding against certain types of radiation (e.g. slow neutrons), though for most radiation the primary need is for a large mass of material. The same respirators, filters, and air pressure systems used to prevent inhalation of poison gas can be used against radioactive dust. Decontamination of ships or vehicles poses comparable problems for chemical and for nuclear contamination. Some medicines can delay or mitigate the early effects of moderate doses of whole-body nuclear radiation.

NON-STRATEGIC NUCLEAR WEAPONS

Most of the remarks so far have dealt with strategic nuclear weapons, and the defences against them. There is, however, a qualitative arms competition in other forms of nuclear weapons as well.

Surface-to-air missiles are undergoing constant improvement. Some of the largest SAMs were fitted with nuclear warheads, thus allowing a very high probability of kill with a single round, and even the possibility of killing more than one aircraft should they be flying in a close formation. The same considerations applied to air-to-air missiles. However, missile guidance has improved to the point that the single shot kill probability of a missile armed with a modern conventional warhead can be quite high. The cost is very much less, and the defence is freed from the difficulties of safe storage in peacetime and timely authorization for employment in wartime. As a result, we are likely to see a reduction in the numbers of nuclear-armed antiaircraft weapons.

Antisubmarine torpedoes have a certain similarity to anti-aircraft guided missiles, in that a direct hit by a conventionally-armed weapon is very likely to destroy the target. However, if a nuclear warhead is used, the lethal radius can be very much increased, so that a near miss will still produce a high kill probability. In the case of depth bombs, for which the miss distance is likely to be quite large, or antisubmarine mines, a nuclear warhead has obvious advantages. But it seems probable that the trend will be toward more accurate delivery of conventional weapons, rather than to increasing dependence on nuclear warheads.

On a battlefield, and on the supply lines leading from the rear up to a battlefield, there is no doubt that nuclear weapons represent a dramatic increase in destructive power. The most reliable and accurate means of delivery is by artillery shells, but here the range is limited. Some extension of range is to be expected by use of devices such as rocket-boosted artillery shells. Several forms of tactical surface-to-surface missiles are in use today, including unguided rockets of poor accuracy. The trend will be towards more accurate guided missiles, whose nuclear warheads may have a selection of energy yields available. Because of the increasing effectiveness of air defences, aircraft are likely to depend more and more on air-to-surface missiles to accomplish the last stage of penetration to their targets. For the same reason, we may see a trend to have more missions assigned to surface-to-surface missiles and less to aircraft, especially for the delivery of nuclear weapons.

Interdiction of the supply lines to a battlefield can be effected by destruction of known fixed targets such as bridges, depots, and supply dumps, for which accurately delivered nuclear weapons greatly increase the probability of rapid success. However, the attack of targets on the move, or whose location will not have been discovered by earlier reconnaissance, is very dependent on the capability for detection and location, together with rapid decision to employ a suitably located nuclear weapon, followed by quick delivery of the weapon while the target is still exposed.

With the improvements in the yield-to-weight ratio of nuclear warheads, it is now feasible to use fighter-bomber aircraft, tactical surface-to-surface missiles, and field artillery pieces, designed for the delivery of conventional warheads, as the launching vehicles for both conventional and nuclear weapons. It may be necessary to fit special arming devices to make the system "Dual Capable", but this is easily done. This adds flexibility to the role of the system. It would, however, complicate the problems of arms control.

As already mentioned, the enhanced radiation weapon offers important advantages in defence against tanks. It would probably be delivered by artillery shells or short-range surface-to-surface missiles. Because of the absorbing and scattering properties of the atmosphere for neutrons and gamma radiation, there would be little reason to build a large "neutron bomb". It is, essentially, a weapon for use at short range.

Finally, a word can be said on the possibility of radiological warfare. As a result of the operation of many nuclear reactors for the generation of civilian electric power, there are now large quantities of highly radioactive fission products stored in many parts of the world. These could be used to contaminate selected areas, denying access for long periods of time, but without producing the more widespread and uncontrollable diffusion of radioactive fallout associated with a nuclear explosion on the ground.

CONCLUSIONS

If there is a "qualitative nuclear arms race" in progress, it is between delivery vehicles and the defences against them, rather than between the designers of nuclear warheads themselves. The warheads can be made with any desired energy yield.

The offence has, and is likely to continue to have, the advantage over the defence, due in large part to the accuracy of modern ballistic missiles. In order to retain survivability, land-based nuclear missiles will probably be made smaller, mobile, and easier to conceal.

The increasing accuracy of guidance will allow antiaircraft and some other types of missiles to achieve high probability of kill without the use of nuclear warheads.

Some of these qualitative developments have important implications for the stability of the strategic nuclear balance. Crisis stability will be threatened by the increasing accuracy of MIRVs, but enhanced by measures such as the mobility of cruise and ballistic missiles which will reduce their vulnerability to a counterforce first strike. Arms control stability may be threatened by the appearance of new systems which motivate the opponent to build a counter system, and by systems whose numbers are difficult to verify.