SECRETS OF THE BOMARC: RE-EXAMINING CANADA'S MISUNDERSTOOD MISSILE

PART 2

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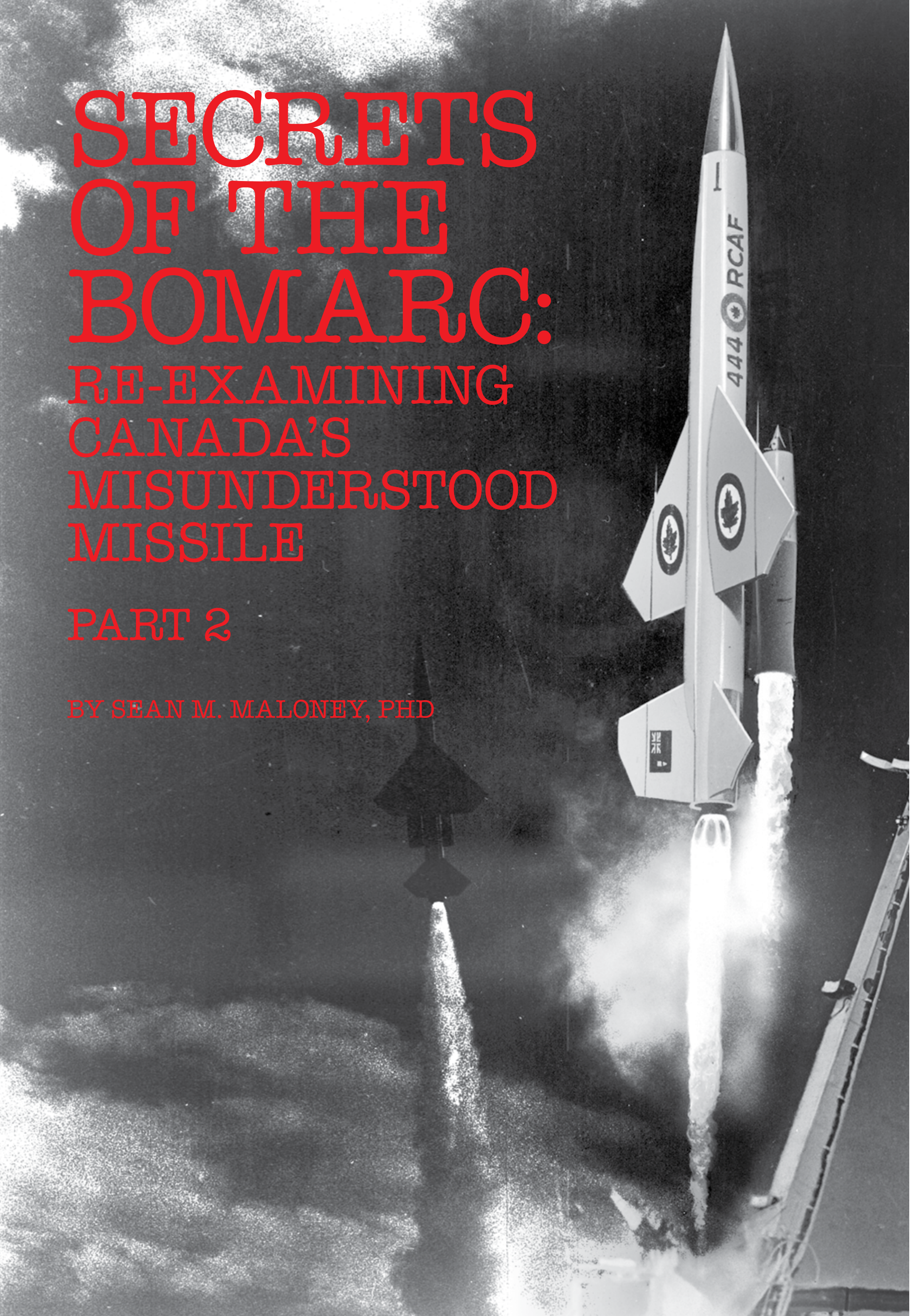

Editor's note: Part 1 of this article examined the development of the nuclear programme in Canada and appeared in the Summer 2014 issue of The Royal Canadian Air Force Journal. *Part 2 delves into the technical aspects of the weapon.*

Testing the strength of nuclear weapons

Although extremely technical, the characteristics of the W-40 warhead become germane to our discussion because they provide us with clues as to the mechanism of the warhead and, thus, its potential capabilities as they relate to the issues discussed previously. All BOMARC[1] launch facilities in the United States (US) and Canada possessed a separate and protected warhead-maintenance building adjacent to the 28 "coffin" launchers.[2] This building consists of a heavily reinforced room with armoured doors and glass, plus eight compartments, each with a garage door. As with any facility that handles nuclear weapons, there are personnel and explosive limits for each structure. These are clearly stenciled on the walls of the compartments. The North Bay BOMARC site weapons maintenance buildings markings include, variously: "Warhead, 1 EA" [each]; "Boost Case, 1 EA"; and "Boost Case Initiators, 4 EA."[3]

In the case of the Canadian BOMARC sites at North Bay and La Macaza, Quebec, the division of labour between the Royal Canadian Air Force (RCAF) crews and the United States Air Force (USAF) nuclear custodian and maintenance detachments was clearly spelled out. No Canadian could enter the warhead maintenance compound or building. The warhead load crews included both Americans and Canadians. The warheads were usually kept in the BOMARC airframe. The access door to the coffin launcher was locked, and the key was held by the USAF custodians. Inside was a "no lone zone," subject to the two-man rule. RCAF personnel handled loading and unloading the W-40 from the airframe, while the American custodians took over at the maintenance building. According to those who were involved in the process, no Canadian ever saw what was inside the "package." Indeed, to this day, even the external photographic image of the W-40 warhead is not available.[4]

What we do know is that the W-40 had a primary device based on the Mark-28 bomb primary and that it was a boosted weapon. A boosted weapon injects a particular type of gas into the centre of the bomb sphere, which then increases the yield of the weapon significantly. In the case of the W-40, that gas was tritium.[5] We also know, like all nuclear weapons, that the W-40 had a neutron generator.[6] In one application, neutrons are used as part of an initiator for the nuclear reaction, and in the past, they were situated in the core's centre. However, with boosting, the initiator was displaced from the core in the design and had to be externally mounted. Another application for neutrons involves a type of kill mechanism, but we will return to this later.

The existence of the boost case is intriguing. There is the plutonium core, then the explosive lens, and finally the beryllium tamper encasing the assembly. Then there is the tritium gas supply and the initiator, which lie outside of the core. Was the boost case simply a container for the boosting system? Perhaps. As discussed earlier, the whole assembly gained an additional 100 pounds [45.3 kilograms (kg)] from the original design specifications. This additional weight was added in 1956. However, the size and, more particularly, the weight of the assembly suggest that the boost case also involved what we now refer to as "tailored outputs."

The more familiar aspects of nuclear weapons use against Japan and the tests in the 1950s tend to reinforce the predominant view of what nuclear weapons do, or how they behave: lots of blast and heat, extensive damage and fallout. However, at some point in the late 1940s and into the 1950s, there was interest in exploiting several other energies released by nuclear explosions and then channeling those energies in creative ways.

Take the W-25 warhead for the Genie, for example. The predominant view of RCAF personnel who were prepared to employ the weapon in the form of the MB-1 Genie from their CF101B Voodoo interceptors viewed it as a "bigger bang"; that is, the nuclear explosive made the blast radius greater and, thus, the explosion more effective against its target. They certainly understood there were other radiological effects. However, the kill mechanism of the W-25 is much more sophisticated than a simple explosively generated blast. The W-25 warhead generates an instantaneous pulse of X-rays that immediately superheat the air around the centre of the blast and rapidly expand it out to 1.16 kilometres (km). There are two types of X-rays: hot and cold. Hot X-rays cause "thermally generated shock waves in the vehicle structural material and internal components, … melting and vaporizing of the substructure, … internal deposition of energy in electronic components producing transient or permanent damage, … or [they] produce internal electromagnetic pulse." Cold X-rays are "absorbed in a thin surface layer … . A short pulse of X-rays can heat the surface rapidly and may cause it to vaporize and blow off."[7]

These effects were measureable at least by 1957 during Shot JOHN, during Operation PLUMBBOB and were incorporated into the engagement sequence used by an interceptor aircraft employing a Genie against an intruding Soviet bomber. Furthermore, the use of a W-25 warhead at high altitude during Shot YUCCA during Operation HARDTACK suggests that the weapon had additional properties that were of value in countering an incoming missile, and those were measurable and available by 1958.

Yet the US decided not to use a W-25 in the BOMARC but to develop a whole new warhead for it; hence the W-40, a heavier weapon that had a supposedly high yield and, thus, greater immediate effects on its target. This is mysterious. Let us compare the estimated, publicly available performance information for the W-25 and W-40. The W-25's visible fireball extends to 1.6 km across. We know that the fusing system on the BOMARC detonated the W-40 at 900 metres from the target which when doubled gives us a 1.8 km radius. The W-25 yields 1.7 to 2 kilotons (kt), while the W-40 yields 7 to 10 kt.[8] Why would a warhead of what appears to be of equivalent value in an engagement but heavier and more intricate be mounted in an incredibly advanced missile airframe that is itself part of a sophisticated air defence tracking network, instead of relying on a relatively simple unguided rocket?

It may be simply a matter of altitude. The BOMARC could be directed by its ground controllers to intercept targets up to 25 km,[9] though the aerodynamic possibilities of the airframe before failure were estimated to be 29 km.[10] The combat operating altitudes for the F-89J or the CF101B interceptors with two Genies on board were around 13.4 km, though there were manoeuvers that existed to loft the Genie to higher altitudes.[11]

As well, there remains the intriguing issue of the additional hundred pounds [45.3 kg]. Why drag a heavier, larger warhead up to 25 km with a ramjet-powered pilotless aircraft when, in theory, the lighter but lower-yield W-25 would permit intercept at even higher altitudes? This leads us to the matter of what the boost case was, what material it consisted of, and what effects it was supposed to generate.

The boost case could have been just that: a container for the tritium gas boosting mechanism. Boost reservoirs are, however, small: 4 or 5 inches [10.1 or 12.7 centimetres (cm)] long.[12] The presence of a boost case initiator suggests that something initiates a reaction, perhaps using the case itself. In thermonuclear weapons, X-rays generated by the implosion core of a fission weapon are not permitted to expand freely; their energy is channeled into a casing that contains thermonuclear fuel and special polystyrene foam that compresses it when subjected to the effects of the primary device.[13] That casing is made of materials, in this case probably Uranium-238, that reflect the X-ray energy symmetrically so it interacts with the polystyrene foam, which in turn interacts with the thermonuclear fuel which consists of a rod of uranium or plutonium surrounded with Lithium-6 deuteride. This is the "secondary" effect in a thermonuclear process.[14]

In essence, the W-40 appears to be a boosted fission weapon with a secondary component that somehow amplifies products of the primary detonation, be it Gamma rays, X-rays, or neutrons. Yet it only yields 7 to 10 kt. Fusion weapons usually yield somewhere in the megaton range. Indeed, regular thermonuclear weapons, when detonated, generate neutrons in an "un-tailored" effect at ranges out to 800 metres.[15]

Logic suggests that there was no thermonuclear fuel in the W-40 secondary. So what did it do and what did it consist of? Is it possible that the boost case was boosting the X-rays, neutrons, or some other output of the weapon beyond 800 metres? If so, then the primary device is of secondary importance in this process, so to speak. The weapon may cause damage like a W-25, but then the whole system put out some other effect to greater distances.

There are notable discrepancies over the period when the W-40 was tested. One source suggests that Shot BOLTZMANN was a 295-pound [133.8-kg] XW-40 warhead tested during Operation PLUMBBOB in 1957. This tower shot yielded 12 kt,[16] while an internal Atomic Energy Commission (AEC) document pegs BOLTZMANN at 11.5 kt with a variable that is redacted.[17] Analysis of available data demonstrates that Shot BOLTZMANN focused on nuclear radiation effects, effects on aircraft structures, and electromagnetic effects on service equipment and material, specifically fireball studies and neutron sources. The US Defense Nuclear Agency report does not identify the warhead type, just the fact that its yield was 12 kt. Foreign observers were present for Shot BOLTZMANN, but not Canadian personnel.[18] Canadian radiation-monitoring teams, however, moved in to the BOLTZMANN detonation site for training in the days afterwards but were disappointed to discover that advice on high "contamination values for BOLTZMANN field were found to be vastly exaggerated," so the team moved to another site that was "hotter."[19] The implication here is that there was not enough radiation on the ground to measure from whatever device was detonated during BOLTZMANN, even though it was fired from a 500-foot [152.4-metre] tower. BOLTZMANN is consistent with a XW-40 warhead test.

The other possible test of a W-40 may have occurred in 1962 at the height of the Cuban Missile Crisis.[20] That test, Operation FISHBOWL, was a high-altitude sub-series of Operation DOMINIC and is shrouded in secrecy. Operation FISHBOWL's initial objectives were:

> To obtain data regarding the interference to radar and communications systems produced by a high-altitude nuclear burst. The data available at present [1961] coupled with theory are sufficient to show that blackout has serious implications for critical defence systems such as BMEWS [Ballistic Missile Early Warning System], Nike Zeus, ICBM [intercontinental ballistic missile] penetration and many communications systems and conversely that its employment may be an effective ICBM offensive tactic.[21]

Specifically, one of the tests involved examinations of X-ray and neutron behaviour in which a detonated weapon was expected to generate "debris" from the blast point out to 1 or 2 km. The event planners expected that "ionizing patches" would form 2 to 4 km wide at 60 to 70 km altitude.[22] In effect, a detonation of a kiloton-yield weapon was estimated to interfere with the environment between 2 and 4 km away from its detonation at that altitude. The hypothesis was that "These effects produce intense and persistent upper atmosphere ionized layers, both in the burst region and at the magnetic conjugate point which cause radio and radar blackout over large areas."[23]

Several of the planned shots required the detonation of devices of 2-kt and 10-kt yields. One test was to "determine X-ray effects on re-entry vehicles and space systems." Two more weapons of unspecified yield were to examine "directed energy effects."[24]

The deterioration of relations between the superpowers brought about by the Cuban Missile Crisis meant that the larger umbrella test series, DOMINIC, received new objectives, including "Evaluation of missile kill mechanisms produced by these events."[25] And, more critically if we are dealing with testing a W-40 warhead:

> The addition of the low-yield, high altitude effects tests were necessary to permit, within limits, evaluation of the utility of such explosions as penetration aids, that is as a precursor burst to permit penetration of ABM [antiballistic missile] defences by an ICBM [4 lines redacted]. In addition to the investigation of the potential of low yield explosions per se, the comparison of observations on such shots with larger yield events would provide better understanding or the variations of high altitude effects with yield.[26]

There is a substantial amount of redacted material. However, of the 35 shots in the test series between April and November 1962, the five shots of the FISHBOWL sub-series stand out. STARFISH, BLUEGILL, and KINGFISH were all high-yield shots using large boosted-fission fusion weapons in the megaton-yield range. Two others are of interest to us: TIGHTROPE and CHECKMATE; both were conducted at the height of the Cuban Missile Crisis in October-November 1962.[27] At these, however, there were no Canadian observers.

TIGHTROPE is believed to have been a test of a W-31 warhead aboard a Nike Zeus missile, but there is some debate over CHECKMATE. Several sources suggest it was a test of a "XW-50I warhead."[28] That is possible, though information on this warhead is difficult to acquire, including its planned purpose. Yet another source described CHECKMATE as "designed for a Thor missile to carry a 125-kt device to an altitude of 483,000 feet [147,218 metres] … utilizing an LASL XW-50X1 warhead launched by [an] … XM-33 Strypi rocket."[29] Another account has CHECKMATE detonating at 147.3 miles [237 km] with less than 20 kt.[30]

However, the fact that CHECKMATE did not use a Nike booster and used an XM-33 Strypi rocket suggests that it was not part of the Nike Zeus testing regime.[31] Examination of photographs of the XM-33 vehicle prior to launch reveals that it had a nose cone and casing remarkably similar in dimensions and shape to the BOMARC's nose cone, and it used a pair of Recruit boosters almost as surrogates for the pair of Marqardt ramjets that were part of the BOMARC airframe. In fact, the XM-33 is uncannily similar to a lash-up BOMARC on its launch stand.[32]

One reported yield of the CHECKMATE event was "under 10 kt," which is consistent with a W-40;[33] though to be fair, there was a 2-kt version of the W-31, and another source asserts the CHECKMATE weapon yielded 60 kt. Other arguments in favour of a W-40 test include the fact that the W-40 had not yet been proof tested as a system, that is, with a launcher, because of the 1959 test moratorium and because other deployed weapons like ASROC [antisubmarine rocket] and Nike Zeus were proof tested with their carriers during DOMINIC. The CHECKMATE detonation occurred "tens of kilometres" over the target area, which would also be consistent with W-40 usage in a BOMARC at 25 km and much less than the suggested 91.3 miles [147 km].[34] On the other hand, a case could be made that the presumably experimental XW-50X1 warhead could have been tested for compatibility with the dimensions of the BOMARC airframe. If so, that suggests that such a warhead, if it yielded 60 kt, could have replaced the 7- to 10-kt W-40 in the BOMARC.[35]

The only other shots in the DOMINIC series that could have been a W-40 test appear to be the TANANA and PETIT events. TANANA yielded 2.8 kt at 2.75 km, while PETIT yielded 3 kt at 14,995 feet [4570 metres] and was "an advanced and novel design" dealing with "highly experimental [deleted]" involving the penetration of air defences.[36]

The results of Operation DOMINIC suggest that:

> Warhead kill radius: AICBM [anti-intercontinental ballistic missile] warhead kill radius is independent of altitudes above 80 to 90 km (and perhaps much lower). It appears that AICBM burst at this altitude and at low dip angles would not seriously degrade the performance of acquisition and tracking radars at UHF [ultra-high frequencies] frequencies and above.[37]

Moreover:

> Valuable data was obtained on the nuclear detonation effects in a possible Nike Zeus tactical situation. The use of a nuclear detonation as an aid to penetration for incoming missiles by disrupting enemy anti-missile missile radars was explored by the STARFISH event [line redacted] … . Effects of a nuclear detonation on incoming re-entry vehicles from X-ray and neutron fluxes, thermal radiation, blast and shock and the vulnerability of our ICBM's.[38]

And, most importantly, by comparing the different types of weapons during the tests, FISHBOWL demonstrated a fascinating phenomenon. According to one analyst, smaller-yield fission weapons produced greater overall "tailored" effects in terms of gamma-ray energy than larger, megaton-yield thermonuclear weapons did.[39] One did not necessarily need a thermonuclear weapon to disrupt incoming ICBMs.

The W-40: Choice of kill mechanism?

By the early 2000s, the US Department of Energy developed a declassification manual in which it updates lists of what can and what cannot be discussed when it comes to nuclear-weapon design and effects. The 2001 edition of the manual notes:

> The fact of existence of weapons with tailored outputs, e.g., enhanced X-ray, neutron, or gamma-ray output; that we are hardening our weapons to enhanced weapon outputs and that high-Z materials are used in hardening nuclear weapons against high-energy X-rays.[40]

And, without directly referencing the W-40, the manual notes: "The size and shape of some thermonuclear weapons: Any information which reveals the existence of thermonuclear weapons with diameter less than 24 inches [60.9 cm] or weight less than 2000 pounds [907 kg] is classified." This was later changed to 18 inches [45.7 cm] and 690 pounds [313 kg].[41] We have a conundrum: the W-40 fits these dimensional criteria and we do not have pictures or even sketches available because these are classified, but does that mean W-40 is a thermonuclear weapon? We have established W-40 is a tritium-boosted fission weapon with a suspicious component that looks like a secondary device of some kind. We also have a number of types of known tailored output kill mechanisms to test against what we have already established. Is it possible to link any of them to the W-40 and BOMARC?

There is an oblique reference in a 1961 RCAF document discussing the 1958 testing moratorium: "The US has apparently developed a new concept of weapon which has to be proven. This has been publicized as the 'neutron bomb' and appears to be a 'clean' weapon. This could revolutionize nuclear weapons and [redacted]."[42] Further discussion was also redacted heavily: "Continuation of the situation is dangerous from the viewpoint of Western security [redacted] of a nature which minimizes fall-out hazard in order to improve its own weapons … ."[43] And: "Anti-Ballistic Missile Development—The balance of power will shift decisively in favour of the first nation to achieve this capability. Nuclear testing is necessary to provide a better understanding of the process of 'killing' an enemy nuclear warhead and to develop a new defensive anti-ICBM warhead."[44]

So was the W-40 an early "neutron bomb"? We are familiar with the controversy over enhanced radiation warheads in a ground role in the North Atlantic Treaty Organization during the 1970s and 1980s. There was a similar controversy in the 1950s over what were called "clean" thermonuclear weapons. A clean bomb design as opposed to a "dirty" bomb (in this case, not a radiological weapon in today's sense) sought to reduce the amount of fallout while still retaining the other effects of a nuclear detonation. The PLUMBBOB and HARDTACK test series in 1957 and 1958 respectively had elements geared towards clean designs, and thus, this coincided with W-40 development.

The clean bomb was a low-fission warhead. The plutonium rod in the secondary device was replaced with another metal which significantly reduced but did not eliminate the fission products of the fusion-fission reaction.[45] Clean weapons were heavier and used more nuclear material.[46] Testing in 1957 and 1958 indicated that "Of prime importance are the biological effects resulting from exposure to the 15 mega-electron-volt energy neutrons that are formed in large numbers by fusion. With the use of 'clean' weapons the biological aspects of the radiation emanating from the fusion process becomes paramount."[47] Later on, a "clean, enhanced neutron output" weapons type was formally identified by the AEC, primarily for use in "antimissile defensive warheads."[48]

What application would it have had in an anti-air role besides irradiating a bomber crew so they could die hours or days after they dropped their bombs? "Neutron flux" from the fusion process was a phenomenon noted during FISHBOWL tests. We have a clue from a retired F-102 pilot who notes that the Falcon missile or

> GAR-11/AIM-26 was primarily a weapon-killer. The bomber(s, if any) was collateral damage. The weapon was proximity-fused to ensure detonation close enough so an intense flood of neutrons would result in an instantaneous nuclear reaction (NOT full-scale) in the enemy weapon's pit; rendering it incapable of functioning as designed. Our strategists assumed enemy weapons, like our own, would be salvage-fused - ie, once over enemy territory armed to function during a crash and thus prevent anyone

> from salvaging the critical material. Back then the weaponeers [sic] also assumed the bigger a bomb the better, thus shooting down the bomber only to have a 20 [megaton] bomb go off at ground level was not really one for our side. Fallout anywhere would be disastrous. Hence the neutron flux. … [O]ur first "neutron bombs" were the GAR-11 and MB-1 Genie.[49]

The GAR-11 used a W-54 warhead designed in 1958 and deployed in 1961 on American interceptors. That made the W-54 contemporaneous with the W-40 but with a much smaller yield: about 1 kt. This suggests that, when effects are compared, the MB-1 Genie's W-25 appears to have generated X-rays as well as neutrons, though this latter effect was inadvertent and supplemental. Nike Zeus, on the other hand, was optimized for X-rays.[50] Later on in the 1960s American ABMs employed both: Spartan used X-rays while Sprint used neutrons.[51] In a general sense, X-rays were optimal as a kill mechanism outside of the atmosphere, while neutrons were optimal inside the atmosphere. BOMARC was an air breather and designed for atmospheric use. Consequently, it is highly likely that BOMARC employed a W-40 warhead that was optimized to generate a burst of neutrons far beyond the range of the 3000-foot [914.4-metre] blast radius of the 7-kt warhead, possibly out to several kilometres.

Those neutrons had very important properties against unshielded systems but particularly against nuclear bombs, be they in the bomb bay of a bomber or in a re-entry vehicle of an ICBM. Both X-rays and neutrons could generate various forms of transient radiation electrical effects and electromagnetic pulse (EMP) inside the target vehicle's systems and fry them so as to render them useless. But neutrons could go to work on the nuclear components of the target bomb itself and generate a condition called "pre-detonation" to generate a "fizzle" or otherwise interfere with the operation of the bomb at some nuclear level. The available information suggests that the W-40's kill mechanism was based on neutron generation, as opposed to X-ray generation, and involved X-rays.

As far as Canada was concerned, the prospect of the Americans detonating W-40 armed BOMARC missiles over Canadian territory during an engagement was worrying. It was one reason why the La Macaza and North Bay sites were positioned where they were, that is, north of the Niagara Triangle. Having a clean warhead on board was preferable to having a standard warhead on board, as there would be fewer fissile products to deal with over and on Canadian territory from the weapon's detonation. Thus, there may have been environmental and social aspects of the W-40 design.

An expedient BOMARC ABM system?

Could the neutron-generating W-40 in a BOMARC airframe have been used to deal with incoming ICBM re-entry vehicles in the 1960s? To do so would have required a number of capabilities. The first component is the means to detect a ballistic track directed against North America. The BMEWS was in place in 1959. It did have teething troubles. However, and this is important, it fed ballistic trajectory data to North American Air Defence (NORAD) headquarters so that the battle staff could rapidly project likely "footprints" where enemy warheads might land. Indeed, as early as 1959, the MITRE Corporation was feeding data to the RCAF on likely ballistic approach routes over Canada. The RCAF, as the Nike Zeus systems were under development, used the information provided by MITRE especially with respect to radar coverage regarding ICBM interception.[52] BMEWS was supplemented by the Shepherd Project, which used the US Navy SPASUR [space surveillance] system to keep an eye on the air-space picture over North America.[53]

Second, the system would have to have some means of tracking the objects once the detection systems saw them. This is where the hypothesis that BOMARC may have had ABM properties starts to become problematic. It is unclear whether the semi-automatic ground environment (SAGE) radars across North America would have had the ability or power to observe objects re-entering the atmosphere at high speeds. Lacking such a capability, the only method of conducting an engagement would have been to predict in which areas re-entry vehicles were likely to arrive and then time a barrage of BOMARC missiles to generate some form of disruptive energy as the warheads arrived. Whether NORAD battle staffs at the regional level had any training to conduct such an engagement and whether there was any doctrine for it is unknown; both issues would seem to be major weaknesses in the hypothesis that BOMARC had some sort of intentional ICBM engagement capability. That said, RCAF work on anti-ICBM projects indicates that there was substantial effort put into connecting early warning with prediction and with engagement, no matter how notional it would have been between 1959 and 1962.[54] And it is clear that a variety of ICBM surveillance and detection systems were already feeding NORAD headquarters by 1961 as evidenced by detailed briefings conducted by Air Marshal Roy Slemon, Deputy Commander-in-Chief of NORAD.[55]

As an example of how much forward thinking there was in RCAF headquarters in 1959 regarding ABM systems, the RCAF kept a close eye on Project MIDAS, a US project designed to use satellites to detect a ballistic missile launch. In addition to MIDAS was Project SPAD, a proposal by the Convair aircraft company, where "it is proposed to place sufficient satellites in orbit to detect ICBM launch and fire one of fifty missiles on each satellite to destroy the ICBM before burnout."[56]

Canada was engaged in several ICBM detection projects from at least 1958 if not earlier. After Sputnik, the Canadian Army Research and Development Establishment (CARDE) set up "five infrared observation stations located across the country for observation of satellite passes" by late 1958.[57]

There was Project LOOKOUT, a "joint RCAF/DRB [Defence Research Board] programme to measure the infrared radiation characteristics of ballistic missiles."[58] For the tests, RCAF CF-100 fighters were modified with wing pods that could detect and record "ultraviolet, visible, and infra-red radiations generated by [missile] nose cones" as they re-entered the atmosphere. These tests took place at Ascension Island and recorded data from American missiles launched from Florida.[59] Another was Project BLIND TWINKLER, which was "undertaken to establish the feasibility of detecting ballistic missiles using reflected sunlight." In this project, CF100s flying from Thule, Greenland, and Churchill, Manitoba, used infrared detection equipment to "determine the magnitude of background signals against which the ICBM's would be detected."[60] Another aspect of BLIND TWINKLER was "to measure scattered sunlight backgrounds in the Arctic sky with a view to determining the feasibility of detecting ICBMs in mid-course using reflected sunlight." Both LOOKOUT and BLIND TWINKLER were considered successful by the DRB.[61] In 1962, CARDE was involved with their American counterpart, the Advanced Research Project Agency, in Project DEFENDER. The Canadian components of DEFENDER included "re-entry physics" and "kill mechanisms."[62]

One must not forget the existence of the Prince Albert Research Laboratory (PARL) in Saskatchewan. PARL was heavily involved with BMEWS research and by the early 1960s appears to have been working on mitigating the effects of high-altitude "communications disruptions" on BMEWS and other detection systems.[63] Established in 1959, PARL was described to President Eisenhower as a "new facility to be used for investigations of the factors influencing the radar detection of aircraft and missiles entering the auroral zone."[64] Canada had a variety of means and expertise in detecting inbound ICBMs.

In terms of terminal target destruction, the make-up of the BOMARC missile presents some positive possibilities. The concept for BOMARC use against aircraft calls for the SAGE computer to direct the missile to a three-dimensional box in airspace. Once the missile arrives, its target-seeker radar is activated and it starts "looking." Once identified, the missile moves to an intercept point where another system determines the distance to the target and then detonates when it is in range. Whether by disrupting the environment or interfering with the internal nuclear make-up of its target, the size and capability of the W-40 warhead makes it a good candidate for killing or disrupting an incoming re-entry vehicle. This is dependent, however, on the sensitivity of a target seeker designed to engage a supersonic aircraft; a re-entry vehicle (RV) would be moving a lot faster. Still, the Soviet RVs of the day (the R-36, UR-100 and RT-2P missiles) would have had large radar cross sections, would have probably lacked penetration aids throughout the 1960s, and may not have been hardened against neutrons and X-rays.

How about the BOMARC's potential engagement zone? The northern tier BOMARC sites were located at Duluth, Kinchloe, North Bay, La Macaza, Niagara Falls and Dow, with the southern chain from Long Island and New Jersey to Langley and Eglin. The slant range of the BOMARC B was 778-km maximum, while intercept altitude is 25–29 km. The potential targets protected by BOMARC in its anti-bomber role would have been the same in any other role: Strategic Air Command bomber bases, command facilities and nuclear storage depots at K. I. Sawyer, Kincheloe, Wurtsmith, Romulus, Griffiss, Westover, Dow, and Loring, plus NORAD command centres and SAGE facilities at Duluth, Sawyer, North Bay, and Syracuse. The Hamilton–Toronto–Ottawa–Montreal corridor and its populated areas would have been covered as well.

The main issue with BOMARC and SAGE in the air-defence role is the same difficulty that confronted the Safeguard ABM programme in the late 1960s and 1970s. What were the short-term or long-term effects of large numbers of nuclear detonations in the upper atmosphere? At what point were specific weapons systems, communications systems, and facilities hardened against those effects? The NORAD command centre at North Bay was hardened by 1963, but were other facilities and systems? The debate over the effects of EMP continues even to this day, and efforts to protect information collected from nuclear tests in the 1950s and 1960s remain active.

What can be said is that a lot of the pieces for an ABM system appear to have been in place in Canada, but there is nothing that connects them from an organizational, policy, or even a doctrinal standpoint. Lacking any further substantiating data, one could only tentatively conclude that BOMARC's ABM properties were employable at the time, but probably not by Canadians. Indeed, it may have been thought of in some quarters as a last resort or a "back-pocket" expedient capability system as opposed to any form of dedicated ABM. But, given the cancellation of Nike Zeus and the anti-ABM policies of the Eisenhower administration, it may have been the only system that had some form of rudimentary capability in this regard.

As for some form of expanded capability for the BOMARC airframe, like the addition of a larger warhead, there is material available that suggests that such a path was contemplated. After the PLUMBBOB test series in 1957 and into the HARDTACK test series in 1958, the Department of Defense requested a feasibility study for a "Warhead in the megaton range for the Air Force surface-to-surface missile, BOMARC."[65] It is unclear where this feasibility study went, but it would have been possible to modify the W-40 to increase its yield into the megaton range. This could have been done with the replacement of elements of the secondary stage. The only issue would have been testing it to make sure the modification worked. The single hint may be Shot CHECKMATE in 1962.

There were also concerns in the 1960s that Soviet anti-aircraft missiles could be readily modified for ABM duty. Indeed, the first Soviet ABM tests were conducted with modified anti-aircraft systems. The primary deployed example was the SA-5 GAMMON, which could loft a 25-kt nuclear warhead to an altitude of 40 km.[66]

Additionally, the removal of the BOMARCs in April 1972 and the signing of the ABM Treaty in May 1972 may not be a coincidence. The ABM Treaty's wording is pertinent:

> The Treaty permits each side to have one limited ABM system to protect its capital and another to protect an ICBM launch area. The two sites defended must be at least 1,300 kilometers apart, to prevent the creation of any effective regional defense zone or the beginnings of a nationwide system … .
>
> There had been some concern over the possibility that surface-to-air missiles (SAMs) intended for defense against aircraft might be improved, along with their supporting radars, to the point where they could effectively be used against ICBMs and SLBMs [submarine-launched ballistic missiles], and the Treaty prohibits this. While further deployment of radars intended to give early warning of strategic ballistic missile attack is not prohibited, such radars must be located along the territorial boundaries of each country and oriented outward, so that they do not contribute to an effective ABM defense of points in the interior.[67]

Perhaps BOMARC's properties were appreciated by and of concern to somebody.

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Abbreviations

ABM	antiballistic missile
ADC	Air Defense Command
AEC	Atomic Energy Commission
AICBM	anti-intercontinental ballistic missile
ATI	Access to Information
BMEWS	Ballistic Missile Early Warning System
CARDE	Canadian Army Research and Development Establishment
cm	centimetre
DHH	Directorate of History and Heritage
DOE	Department of Energy
DRB	Defence Research Board
EA	each
EMP	electromagnetic pulse
FOIA	Freedom of Information Act

ICBM	intercontinental ballistic missile
kg	kilogram
km	kilometre
kt	kiloton
LAC	Library and Archives Canada
NORAD	North American Air Defence
PARL	Prince Albert Research Library
RCAF	Royal Canadian Air Force
RG	Record Group
RV	re-entry vehicle
SAGE	semi-automatic ground environment
SAM	surface-to-air missile
SPASUR	space surveillance
US	United States
USAF	United States Air Force

Notes

1. BOMARC is derived from Boeing Michigan Aeronautical Research Center.

2. The launch containers for the BOMARC missiles resembled coffins, hence the nickname.

3. Author's observations at the derelict North Bay BOMARC launch facility.

4. During the course of research for *Learning to Love the Bomb,* I spoke with a number of former RCAF personnel involved in BOMARC operations. I have drawn on these discussions for this information.

5. Chuck Hansen, *US Nuclear Weapons: The Secret History* (New York: Orion Books, 1987), 220.

6. Freedom of Information Act [FOIA], "ADC [Air Defense Command] Historical Study No. 21, BOMARC and Nuclear Armament 1951–1963."

7. FOIA, Defense Nuclear Agency, "Defense Nuclear Agency Effects Manual Number 1: Capabilities of Nuclear Weapons 1 July 1972," 9–67.

8. See "ADC Historical Study No. 21, BOMARC and Nuclear Armament 1951–1963"; and "ADC Historical Study No. 20, Nuclear Armament: Its Acquisition, Control and Application to Manned Interceptors 1951–1963," for radii; and see Hansen *US Nuclear Weapons*, for weapons yields.

9. "BOMARC and Nuclear Armament."

10. Hendrick Diary, 9 July 1958, Directorate of History and Heritage [DHH].

11. Keven Keaveney, *McDonnell F-101B/F* (Arlington: Aerofax, 1984), 9.

12. See Charles R. Loeber, *Building the Bombs: A History of the Nuclear Weapons Complex*, 2nd ed. (Albuquerque: Sandia Laboratories, 2005), 97.

13. See Howard Morland, *The Secret That Exploded* (New York: Random House, 1981), 271.

14. Ibid., 278.

15. Ibid., 90.

16. Robert Norris and Thomas Cochran in the Natural Resources Defense Council study NWD 94-1, "United States Nuclear Tests July 1945 to 31 Dec 1992" (1 Feb 1994).

17. FOIA DOE [Department of Energy] (no date), Redacted Operation PLUMBBOB yield list, likely from a quarterly report of the Joint Committee on Atomic Energy's Weapons annex.

18. Defense Nuclear Agency United States Atmospheric Nuclear Weapons Tests Nuclear Test Personnel Review, "PLUMBBOB Series 1957." Note that the experiments during BOLTZMANN related to neutrons was deleted from the Defense Nuclear Agency report.

19. Library and Archives Canada [LAC], Record Group [RG] 24, vol. 21444, file 1894-2, "Report of Working Party PLUMBBOB II 10 Jul–17 Jul 57."

20. Hansen, *US Nuclear Weapons*, 195.

21. FOIA, Headquarters Air Force Special Weapons Center Air Force Systems Command Kirtland Air Force Base, New Mexico, "Preliminary Plan for Operation FISHBOWL, November 1961."

22. Ibid.

23. Ibid.

24. FOIA, Defense Atomic Support Agency (DASA) [15 May 1962] memo for Secretary of Defense, "Program Change Proposal for DASA."

25. FOIA, "Enclosure L to the Report by Commander Joint Task Force Eight on the 1962 Pacific Nuclear Tests (Operation DOMINIC) Scientific Summary."

26. Ibid.

27. Defense Nuclear Agency, "United States Atmospheric Nuclear Weapons Tests Nuclear Test Personnel Review: Operation DOMINIC 1 1962."

28. William Robert Johnston, "High Altitude Nuclear Explosions." Nuclear Weapons Archive, accessed June 23, 2014, http://nuclearweaponarchive.org/Usa/Tests/Dominic.html, suggests it was a weapon detonated at 91 miles [146 km] at 60 kt. This is not specifically sourced on the website, so it is difficult to verify. Robert Norris and Thomas Cochran in the Natural Resources Defense Council study NWD 94-1, "United States Nuclear Tests July 1945 to 31 Dec 1992" (1 Feb 1994) also identify CHECKMATE as an XW-50X1 warhead detonated at 91.5 miles [147 km]with a "low" kilo-tonnage yield. This data is not specifically sourced either.

29. National Association of Atomic Veterans, "The Newsletter for America's Atomic Veterans," March 2012, 4. The article then goes on to repeat the "W-50, 91-miles [146 km]–60 kt" information used in the other sources.

30. Jerry Emanuelson, "Operation FISHBOWL," accessed June 23, 2014, http://www.futurescience.com/emp/fishbowl.html.

31. "Operation DOMINIC 1 1962."

32. Ibid. See XM-33 picture on page 223.

33. The 10-kt figure comes from www.wikipedia.org/wiki/OperationFISHBOWL note 5, R. G. Allen Jr, Project Officer, Report ADA 995365, "Operation DOMINIC: Christmas Island and FISH BOWL Series Project Officers Report Project 4.1," 30 March 1965, 17. Unfortunately, this document has subsequently been discontinued since the author viewed it.

34. Peter Kuran's excellent 1999 documentary "Nukes in Space" uses declassified footage of all the FISHBOWL tests except CHECKMATE.

35. On the whole, there appears to be substantial misinformation about the CHECKMATE shot, with certain information being repeated uncritically in a variety of sources. This is unlike any of the other tests in the FISHBOWL series. My sense is that there was an attempt from a very early stage to obscure exactly what was tested, exactly what the test results were, and that we are seeing the long-term effects of that decision. As to the motivations, that must remain open to speculation for the time being. CHECKMATE remains mysterious whether or not it had anything to do with BOMARC and W-40.

36. FOIA, "Enclosure L to the Report by Commander Joint Task Force Eight on the 1962 Pacific Nuclear Tests (Operation DOMINIC) Scientific Summary."

37. Ibid.

38. Ibid.

39. See Ed Thelan's logic on this issue, accessed June 23, 2014, www.ed-thelen.org/EMP-ElectroMagneticPulse.html.

40. US Department of Energy Office of Declassification, "Restricted Data Declassification Decisions 1946 to the Present," (RDD-7) January 1, 2001, 53.

41. Ibid., 57.

42. Access to Information [ATI] memo, J. C. Arnell, Chief of the Air Staff / Scientific Advisor, "Minute 2: The Testing of Nuclear Weapons," 10 July 1961.

43. ATI memo, F. R. Miller CCOS [Combined Chief of Staff] to Chiefs of Staff Committee, 4 July 1961.

44. ATI Joint Staff, "The Testing of Nuclear Weapons," 30 June 1961.

45. FOIA, DOE Chairman of the AEC Seaborg to President John F. Kennedy, "Nuclear Test Program," 19 September 1961.

46. FOIA, DOE, memo AEC (Morse) to Dearborn (Special Assistant to the President), "Reasons for Further Nuclear testing," 20 January 1958.

47. FOIA, DOE (27 June 1963) US Army Surgeon General memo Lanard, Young and Taylor to Blount.

48. FOIA, DOE Los Alamos Scientific Laboratory, "Proceedings of the Tactical Nuclear Weapons Symposium, 3–5 September 1969."

49. Sean O'Connor, Technical Report APA-TR-2011-0601, "Arming America's Interceptors: The Hughes Falcon Missile Family," accessed June 23, 2014, http://www.ausairpower.net/Falcon-Evolution.html.

50. *History of Strategic Air and Ballistic Missile Defence,* Volume II 1956–1972, 200, accessed June 23, 2014, http://www.history.army.mil/html/books/bmd/BMDV2.pdf.

51. Abram Chayes et al., *ABM: An Evaluation of the Decision to Deploy an Anti-Ballistic Missile System* (New York: Harper and Row, 1969), 7.

52. DHH, 79/429 vol 9, Divisional Items of Interest, Analysis of AICBM Systems, 10 April 1959.

53. FOIA, Defense Research and Engineering, "Report No. 10 Military Space Projects March-April-May 1960." See SPASUR graphic depicting coverage.

54. A perusal of the Vice Chief of the Air Staff's records confirms that the A/ICBM topic was one of the dominant issues during that time.

55. DHH, Raymont Collection, File 2008, "Shorthand Transcript of 1961 Air Officers Command Conference," 21 March 1961.

56. DHH, 79/429 vol 9, Divisional Items of Interest, Analysis of A/ICBM Systems, 10 April 1959.

57. LAC, RG 24, acc 83-84/167 vol. 7407, file 173-1 pt 1, (24 Jun 58) DRB Meeting June 1958 Review of Progress."

58. Ibid., (8 June 1962) DRB "A Resume of Major DRB Activities."

59. "The Cameras Saw Red," *The Roundel* March 1961, 13–15; "Missile Monitors," *The Roundel* May 1962, 15.

60. LAC, RG 24, acc 83-84/167 vol. 7407, file 173-1, pt 1, DRB "A Resume of Major DRB Activities," 10 April 1959.

61. Ibid.

62. LAC, RG 24, acc 83-84/167 vol. 7407, file 173-1, pt 1, DRB, "Cooperative and Joint DRB/USA [United States of America] Projects Operating Within the Board," 23 May 1962.

63. LAC, RG 24, acc 83-84/167 vol. 7407, file 173-1, pt 3, "Summary of Activities for Board Meeting on 30 October 1964."

64. University of Saskatchewan, Diefenbaker Papers, Reel 26, Press Release, "The White House," 6 June 1959.

65. FOIA, DOE AEC, "Part III-Weapons-Quarterly Progress Report to the Joint Committee on Atomic Energy, October-December 1957," 24 February 1958.

66. See Sean O'Connor, "Russian/Soviet Anti-Ballistic Missile Systems," accessed June 23, 2014, http://www.ausairpower.net/APA-Rus-ABM-Systems.html; and Carlo Kopp, "S-200VE Vega SA-5 GAMMON Missile Site Design," accessed June 23, 2014, http://www.ausairpower.net/APA-S-200VE-Vega-Sites.html.

67. The treaty wording, accessed June 23, 2014, http://www.state.gov/www/global/arms/treaties/abm/abm2.html.