PLRC Pacific Life Research Center

631 Kiely Boulevard * Santa Clara, CA 95051 * Phone 408/248-1815 * Fax 408/985-9716 * E-mail bob@plrc.org

PLRC-990628A This paper is current only to 17 December 2002

CONVENTIONAL ALCMs:
A BACKGROUND PAPER ON CONVENTIONALLY-ARMED AIR-LAUNCHED CRUISE MISSILES (CALCMs)

Compiled by Bob Aldridge

Air-launched cruise missiles (ALCMs) started in the 1970s as a strategic nuclear delivery vehicle. In October 1986 Boeing completed production of 1,739 nuclear-tipped ALCM-Bs at its Space Center in Kent, WA. Since the end of the cold war these weapons have been put into storage and many have been converted to carry conventional bombs. These so-called conventional air-launched cruise missiles (CALCMs), have now joined the conventionally-armed Tomahawk sea-launched cruise missiles as the US military's weapon of choice for regional wars. This paper will focus on the CALCM.[1]

DESCRIPTION

The CALCM, also known as the AGM-86C, was developed in the late 1980s by modifying nuclear ALCMs. It is launched from an aircraft, most commonly a B-52H bomber which can carry up to 20 (four internally on a rotary rack and six clustered on a pylon under each wing). After it is released from the aircraft the wings and tail unfold and a miniature fanjet engine (same as Tomahawk) starts up to propel the missile at subsonic speeds. The CALCM uses the NAVSTAR Global Positioning System (GPS) satellite constellation for navigation updates to its inertial system.[2] Target coordinates are fed into the missile's on-board computer before it is launched from the aircraft, and the GPS then guides the missile to that target.

The missile stays at a high altitude until it reaches hostile territory. Then it descends to treetop skimming height until it reaches the target area The longer it can stay at a high altitude, the farther it can fly. Its nominal range is advertised as 600 nautical miles but its specific range is secret. For the final approach, if there is a digital image of the target, the CALCMs infrared radar seeks it out. Missions for the ALCM are planned at Offutt Air Force Base in Nebraska. The complete missions are then sent to the base where the B-52Hs and B-1Bs carrying CALCMs are stationed. Preparing the bomber and loading it with CALCMs takes about 24 hours.[3]

---

[1]For a more complete history of cruise missiles, including ALCMs, see Aldridge, pp. 141-149.

[2]See PLRC-980312 for a description of NAVSTAR GPS.

[3]See Appendix-A for CALCM characteristics and specifications.

Presently, CALCMs can be equipped with a variety of conventional and non-conventional warheads (including non-lethal energy warheads such as high radio frequency generators, electromagnetic generators, or microwave frequency generators -- all designed to destroy enemy electronics). However, according to available information, CALCMs now appear to be used mainly as penetrating, bunker busting munitions. Tomahawks, which require a rocket motor to boost them to speed and altitude and therefore cannot carry as heavy a bomb, seem more suitable for other missions, when they are available for use.

B-52 launching an ALCM

1. AGM-86C, Block-0 CALCMs.

The first ALCM modifications were started by Boeing in the June 1986 for $380,000 per missile, but it is unknown how many were modified. Successful flight tests took place within a year and the last of the contract was delivered in June 1993. This modification included replacing the terrain contour matching (TERCOM) guidance system with GPS receivers integrated with the existing on-board inertial navigation system. It also included substituting a 1000-2000 pound conventional fragmentation warhead for the nuclear bomb. These first CALCMs were designated Block-0.

2. AGM-86C, Block-1 CALCMs.

In June 1995 Boeing was awarded a contract to convert 100 missiles to the AGM-86C, Block-1 design. This was identified as Lot 1. In March 1996 Boeing received a second contract for another 100 AGM-86C, Block-1 conversions, identified as Lot 2. Block-1s have a larger and improved conventional warhead of the 3000 pound class encased in a hard shell (probably of depleted uranium). A multi-channel GPS receiver was installed and the avionics package updated.

In December 1996 Boeing demonstrated that, using precision on-board GPS optimization (a third generation GPS receiver) along with advanced navigation software and anti-jam characteristics in a CALCM, that the missile could loiter for 4.5 hours and then perform a steep dive to impact within 2.5 meters (8.2 feet) of the target. A fast and steep dive increases the effectiveness of warheads to penetrate a hard target.. Shallower dive angles are also possible in order to be effective against a wider spectrum of targets. This precision strike capability was designated Block-1A. It can deliver a 3,000 pound warhead over a distance of 600 miles. All existing Block-0 and Block-1 missiles are being retrofitted to the Block-1A configuration. The contract was awarded in April 1998. In April 1999 the USAF awarded Boeing a $41 million contract for another 95 CALCM conversions to replace weapons used in Desert Fox (see below). This contract was later increased to $122 million to convert 322 of the nuclear ALCMs to the conventional version. Deliveries are to be completed in 2001. The last 50 of these will be equipped with deep penetration warheads (see

AGM-86D below). On 20 September 2001, following the terrorist attack on the US, the Air Force awarded Boeing a $6.2 million contract to finish installing conversion kits into the remaining 207 AGM-86C CALCMs. Presumably this brings all 322 CALCMs up to the AGM-86D configuration.

3. AGM-86D, CALCMs.

The AGM-86D missile will have the 3-meter (9.8-foot) precision strike accuracy of the AGM-86C, Block-1A CALCMs plus an advanced penetrating warhead to destroy very hard and deeply buried targets. Two of these bunker busting warheads are in development. Funding for AGM-86D CALCMs was included in the fiscal years 1999-2001 budget. Flight tests are scheduled for the second quarter of 2001. The first 50 warheads were expected to cost $800,000 each. Boeing Military Aircraft and Missile Systems Group (Seattle, Washington) was on 27 April 2001 awarded a $5.35 million modification to a previous contract to provide Phase-3 of the Penetrator modification supporting conversion of AGM-86B nuclear ALCMs to AGM-86D CALCMs. Phase-3 completes conversion of 48 missiles and 4 training missiles. Work is to be completed by July 2002.

a. Bomb Royal Ordnance Augmented Charge (BROACH). The bunker buster warhead on Block-1 CALCMs could be of British design. In February 1997, British Aerospace plc. (BAplc) was awarded a $10-million US Air Force contract (under the USAF's Foreign Comparative Test Program) to develop the earth-penetrating BROACH based on the shaped-charge, armor-piercing technology of World War II. BROACH is a dual-charged warhead to penetrate concrete and steel shelters covered by several feet of dirt. Experimenting was also done by the USAF's Cruise Missile Product Group at Tinker AFB, Oklahoma.

BROACH was tested on a CALCM forebody in a dynamic sled test at the Pendine Test Range in Wales in May 1998, where at a speed of 1000 feet/second it penetrated a steel reinforced, 12 foot thick concrete target. Two verification tests were conducted on a rocket sled in October 1998 at Eglin AFB, Florida.

Prime contractor for BROACH is BAplc's Royal Ordnance subsidiary (Chorley, England). Also part of the joint effort is Thompson Thorne Missile Electronics Ltd. (Basingstoke, England)which makes the fuzing electronics. The Defense Systems segment of Raytheon (Tucson, AZ) makes the penetrator. The Defence Evaluation and Research Agency of the British Ministry of Defence provides research expertise and computer modeling. Gen Corp's Aerojet unit (Sacramento, CA) provides product engineering and integration.

b. Advanced Unitary Penetrator (AUP-3M) Warhead. Another penetrating warhead design has been tested by the Pentagon's Defense Special Weapons Agency (Alexandria, VA). That agency awarded a $2.5 million contract to Lockheed Martin Missiles & Fire Control(Dallas, TX and Orlando, FL) to develop a kinetic energy bunker buster called the Advanced Unitary Penetrator (AUP-3M). Sled tests of that design also took place in the fall of 1998.

4. Follow-On To CALCM.

It would be prohibitively expensive to re-open the production line to build more CALCMs when there are no more nuclear ALCMs available to convert. The Air Force plans that the Joint Air-to-Surface Standoff Missile (JASSM) will replace CALCMs after 2001. The problem with this plan is that JASSMs will probably only have half of CALCM's range. The JASSM is a $3 billion cruise missile program to build 2400 missiles. Full scale production is to start in 2002. Lockheed Martin

Corp. has been awarded this Air Force contract. Failure of the Teledyne-supplied J-402 engine to meet the range requirements may delay this schedule.

Another possibility which has not been publicly mentioned is that a planned Tomahawk replacement -- Fasthawk -- may have an air-launch capability. Using Fasthawk would consolidate production and provide some interchangeability between the air-launched and sea-launched versions. In August 1998 Boeing was awarded a $10-million, 18-month contract to design and test two prototype Fasthawks. If that is successful, a 30-month production and flight demonstration contract may follow.

THE WEAPON OF CHOICE

Air-launched CALCMs have teamed with sea-launched Tomahawk cruise missiles as the weapon of choice for the US military. This has been restated many times by military commanders. The reasons for this were succinctly pointed out by a 1995 US General Accounting Office (GAO) report: "The cruise missile's performance ... demonstrates that military commanders have a new option for highly accurate strike applications under a variety of conditions.... cruise missiles struck targets at night, in bad weather, or in the face of heavy air defenses without risking the loss of aircraft and the death or capture of US aircrew members."[4] In addition to these advantages over strike aircraft, cruise missiles:

-- can strike a variety of targets;
-- do not need additional resources such as electronic warfare aircraft, fighter escort, or refueling aircraft;
-- do not require a carrier battle group;
-- avoids possible political restraints of a host nation for bases or overflying; and
-- require enemy defenses to encounter each missile, which is small and flies low, making it difficult to detect.

There have been other affirmations that cruise missiles are at center stage in Pentagon planning. "Cruise missiles, delivered by sea or air, are the weapon of choice," stated Zalmay Khalilizad, strategic studies director at Rand Corp. and former assistant deputy undersecretary of defense during Desert Storm.[5] "These have been the centerpiece of the Clinton doctrine," added John Ilillen, senior fellow for political/military affairs at the Center for Strategic and International Studies.[6]

Although cruise missiles are not the most economical weapon for extended offensive air wars such as that against Yugoslavia, they do fulfill a military purpose for attacks before support services for aircraft are available and for attacks against heavily defended targets. CALCMs now compliment Tomahawks as this weapon of choice because they are more effective in penetrating harder targets such as underground command posts, weapons bunkers, and clandestine manufacturing locations. Let us look at how this capability has evolved.

---

[4]GAO/NSIAD-95-116, p. 33.

[5]Cited in Borenstein.

[6]Cited in Borenstein.

1. Operation Desert Storm.

CALCMs first became operational in 1991 when seven B-52H bombers took off from Barksdale Air Force Base in Louisiana on January 16th, flew 35 hours and 14,000 miles, and launched CALCMs against Iraq. These Block-0 weapons used in Desert Storm were delivered by the longest air combat mission in history.

The seven B-52Hs carried 39 CALCMs and successfully launched 35 of them on the first day of the war. At that time the CALCMs flew a pre-programmed route with periodic GPS updates. They could be retargeted aboard the aircraft before they were launched, but once on the way there was no more communication with them. Although CALCMs attacked 2 of the 12 target categories, they were not used against Baghdad because they were not considered accurate enough.[7] (This was the first time GPS had been used with cruise missiles and there was more confidence in the Tomahawks which used TERCOM for navigation updates.) Also at that time CALCMs only carried a 1000-2000 pound fragmentation bomb which had no penetrating capability and were therefore not effective against hardened targets.

2. Operation Desert Strike.

On 2 September 1996 there were 13 CALCMs launched against eight Iraqi air defense sites during a joint attack with the Navy. This was a punitive strike in response to continued hostilities against the Kurds in northern Iraq. This operation set the stage for future modifications and introduction of the Block-1 model.

3. Operation Desert Fox.

During 16-19 December 1998 the US and Britain bombarded Iraq with 330 Tomahawks and some 90 CALCMs of the Block-1 configuration. Fifteen B-52H bombers flew from Guam to deliver the bunker-busting CALCMs.

4. Operation Allied Force.

During the first six days of the attack on Yugoslavia, which began 24 March 1999, the US launched 55 Tomahawks and about 50 CALCMs. The latter were delivered by seven B-52H bombers which flew from RAF Fairford in Gloucestershire, England. When those bombers flew to RAF Fairford just prior to the attack on Yugoslavia, they were carrying 112 CALCMs.

B-2 bombers also made a 30-hour round trip raid over Kosovo from their Whiteman Air Force Base in Missouri. It was not revealed what type of munitions they carried.

5. Preparing For Future Wars.

The Pentagon is now looking at better ways to strike opponents with conventional weapons launched from its heavy bombers (B-52s, B-1s, and B-2s). Currently these bombers are all based in the continental United States. In anticipation of hostilities in Korea, Taiwan, or other places in the Asia-Pacific region, CALCMs are now being stockpiled at Anderson Air Force Base on Guam. This is the first time these missiles have been stored outside the continental US. From Guam, the B-52s can reach any location in Asia within 12 hours. Three other "forward operating locations" are being considered by the US military: the island of Diego Garcia in the Indian Ocean, Royal Air Force Base Fairford in Britain, and some undisclosed Middle East location.

---

[7]CALCMs attacked 5 military communications sites and 3 electrical powerplants during Desert Storm.

CURBING OUR CULTURE OF VIOLENCE

There are many good reasons for stopping further production and use of cruise missiles. These reasons range from economics to humanitarian, from treaty negotiations and international relations to domestic security and terrorism avoidance. But perhaps the most important reason for us as a nation is to rein in the culture of violence which is breeding throughout the land and infesting our society.

Long-range cruise missiles, specifically Tomahawks and CALCMs, have become popular with military planners and have been sold to the US public because they provide air strikes without risking a pilot's life. It has become acceptable to bomb other nations -- from Sudan to Afghanistan, from Iraq to Yugoslavia -- so long as there are no American casualties. We in this country are insulated from the carnage those "weapons of choice" reap in the places they are used. Unlike the Vietnam war days, we do not see atrocities perpetrated for media cameras to record. We can not imagine the death and destruction as we could in the 1960s, and which caused so much public outrage at that time, because we can no longer view the graphic details on television. Occasionally when something is sensational enough to attract media attention, such as mistakenly bombing a convoy of refugees, the reporters plays it up big. But even then we only see the aftermath, not the actual event.

These "weapons of choice" are having a subtle and extremely devastating effect on our culture. Since cruise missiles were first used during the 1991 Persian Gulf war, we Americans have been tolerating a permanent state of war. The effects on our young people are particularly ravaging. Helping to restore feeling and compassion into America's conscience, now being systematically numbed by military expediency, would perhaps be the greatest advantage of all from stopping production and use of cruise missiles, including the CALCMs.

#####

REFERENCES

Aldridge, Robert C.; First Strike: The Pentagon's Strategy for Nuclear War (Boston, South End Press, 1983).

Boeing News Release, 13 June 1995.

Borenstein, Seth and Parker, Richard; "Running Low: Air Force Has 100 Cruise Missiles Left," *Mercury News* (San Jose, CA), 31 March 1999, pp. 1A & 17A.

Burgess, Lisa; "Warhead Turns Standoff Missiles Into Bunker Busters," *Defense News*, circa July 1998.

"Cruise Missile Supply At Issue," News Edge Corp. (NewsPage.com), 31 March 1999.

GAO/NSIAD-95-116 -- *Cruise Missiles: Proven Capability Should Affect Aircraft and Force Structure Requirements*, US General Accounting Office report, April 1995.

Mintz, John; "Boeing Lobbies For Missile Contracts," *Mercury News* (San Jose, CA), 18 April 1999, p. 20A.

"New Secret Cruise Missile Opened Gulf War," *The Sun* (Bremerton, WA), 17 January 1992.

Starr, Barbara; "US Considers Options To Restock Arsenal Depleted By Gulf Strikes," ABC News.com, 1 January 1999.

US Air-Launched Cruise Missile, http://www.softwar.net/agm86.html

USAF Fact Sheet: AGM-86B/C Missiles.

GLOSSARY

AFB	Air Force Base.
AGM-86C	Official military designation for the CALCM. AGM stands for air-to-ground missile.
ALCM	Air-Launched Cruise Missile.
BAplc	British Aerospace plc.
BROACH	Bomb Royal Ordnance Augmented Charge.
CALCM	Conventional Air-Launched Cruise Missile.
GAO	General Accounting Office.
GPS	Global Positioning System.
JASSM	Joint Air-to-Surface Standoff Missile.
NAVSTAR	NAVigation System Targeting And Ranging. A constellation of navigation satellites.
RAF	Royal Air Force (British).
TERCOM	Terrain COntour Matching. A sensor originally used in long-range cruise missiles.
US	United States.
USAF	United States Air Force.

APPENDIX-A
CALCM CHARACTERISTICS & SPECIFICATIONS
Source: USAF Fact Sheet (modified)

Primary Function: Cruise missile for air-to-ground strikes.
Prime Contractor: Boeing Defense and Space Group.
Guidance Contractors: Litton Guidance and Control.
Interstate Electronics Corp.
Power Plant Contractor: Williams Research Corp. for the F-107-WR-10 turbofan engine.
Engine Thrust: 600 pounds.
Length: 20 feet, 9 inches (6.3 meters).
Weight: 3,150 pounds (1,429 kilograms).
Diameter: 24.5 inches (62.23 centimeters).
Wingspan: 12 feet (3.65 meters).
Range: 600 nautical miles (nominal); classified (specific).
Speed: high subsonic (nominal); classified (specific).
Guidance System: Litton inertial navigation system element integrated with onboard GPS.
Warheads: Block-0 -- 1000-2000 pound class fragmentation bomb.
Block-1 -- 3000 pound class penetration blast bomb.
Unit Cost: $160,000 (current cost to convert an existing nuclear ALCM to a CALCM).
Total cost of a Block-1 CALCM is $1.9 million in 1999 dollars..
Date Deployed: 16 January 1991 in strike against Iraq.
Inventory: In April 1999 there were 90 CALCMs left in inventory.
There are 1142 nuclear ALCMs left.
USAF in April 1999 awarded Boeing a $41 million contract to convert 95 nuclear ALCMs to CALCMs.