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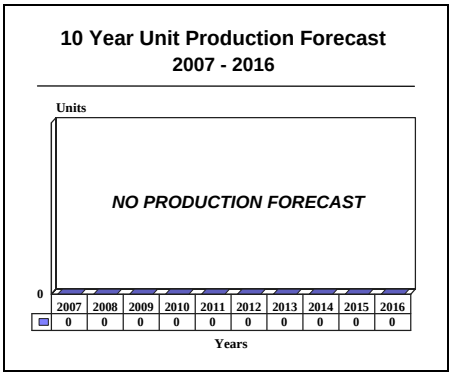
AGM-109/BGM-109 Tomahawk - Archived 01/2008

Outlook

- Production has concluded
- U.S. has made extensive use of Tomahawk cruise missiles in military operations launched since 1990
- Tomahawk Block III will remain in U.S. service for an extended period
- 802 Tomahawk Block IIIs were used during the opening phase of Operation Iraqi Freedom



Orientation

Description. Multipurpose, multilaunch platform conventional/nuclear cruise missile.

Sponsor. The United States Department of Defense through the U.S. Navy Naval Air Systems Command, Program Executive Office (PEO) for Strike Weapons and Unmanned Aviation, Patuxent River, Maryland (MD), USA.

Status. Production of Block III missiles should cease in the near future unless the U.S. extends its purchases in response to Operation Enduring Freedom and the war in Iraq. Thereafter, the U.S. will manufacture the new Tactical Tomahawk (see separate report). The U.S. has decided against pursuing the Tomahawk Baseline Improvement Program (TBIP), also known as Block IV, in favor of the Tactical Tomahawk.

Total Produced. Approximately 525 ground-launched cruise missiles (including 61 RDT&E units), 59 AGM-109 air-launched cruise missiles (all RDT&E or flight test units), and 6,052 sea-launched cruise missiles (of all types, including remanufactured and over 120 RDT&E units) were completed over the life of this program.

The U.S. Tomahawk inventory goal was roughly 3,000 Block II and Block III missiles, of which 1,300 were to be the latter, by the end of 1999. The U.S. had 3,000 Tomahawks, but only 2,200 were said to be operational in January 1999. Of these, 790 are capable of being launched from submarines; the remaining 1,410 are intended for surface combat. The current U.S. Tomahawk Block III inventory may be no more than 2,000 missiles.

Application. Launched from submerged submarines, surface vessels, and mobile ground launchers against tactical or strategic land- and sea-based targets.

Price Range. FY90/91 documents list the Navy's BGM-109 at $1,619,422 per missile in FY89 dollars. The last Air Force BGM-109 price listed was $2,034,081 for each ground launch cruise missile in FY88 dollars. FY91 budget documents quote a per-unit price of $1,347,888. The FY92/93 documents state $1,924,250; the FY97 budget, $737,608; and the FY98 budget, $797,230. The U.S. government places the Tomahawk competitive price at $1.1 million per unit. The cost of the Block III conversion has been estimated at $312,000 per missile; the engine upgrade alone will cost $50,000. The Tactical Tomahawk has a per-unit price of $559,000.

AGM-109/BGM-109 Tomahawk

Contractors

Prime

Raytheon Missile Systems, Strike Product Line	http://www.raytheon.com/businesses/rms/, PO Box 11337, Tucson, AZ 85734-1337 United States, Tel: + 1 (520) 663-6941, Fax: + 1 (520) 663-9804, Prime

Subcontractor

Aerojet	http://www.aerojet.com, 5731 Wellington Rd, Gainesville, VA 20155 United States, Tel: + 1 (703) 754-5000 (Solid Rocket Motor)
Honeywell Aerospace, Defense & Space Electronic Systems - Minneapolis	http://www.honeywell.com/sites/aero/, 2600 Ridgway Pkwy, Minneapolis, MN 55413 United States, Tel: + 1 (612) 951-6444, Fax: + 1 (612) 951-6516 (APN-194 Radar Altimeter)
Kaman Aerospace - Fuzing Division (MDL)	http://www.kamanaero.com/fuzing.html, 217 Smith St, Middletown, CT 06457-9990 United States, Tel: + 1 (860) 632-1000, Email: fuzing-kac@kaman.com (FMU-138/B Fuse)
Northrop Grumman Navigation & Space Sensors Division	http://www.nsd.es.northropgrumman.com, 21240 Burbank Blvd, Woodland Hills, CA 91367-6698 United States, Tel: + 1 (818) 715-2470, Fax: + 1 (818) 715-3368 (LN-100 Ring Laser Gyroscope (RLG) Inertial Navigation System (INS))
Williams International	http://www.williams-int.com, 2280 E West Maple Rd, PO Box 200, Walled Lake, MI 48390 United States, Tel: + 1 (248) 624-5200, Fax: + 1 (248) 669-0040 (F107-WR-400; F107-WR-402)

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Contractors are invited to submit updated information to Editor, International Contractors, Forecast International, 22 Commerce Road, Newtown, CT 06470, USA; rich.pettibone@forecast1.com

Technical Data

Design Features. The basic airframes for all Tomahawk missile models are similar. A long, cylindrical body tapers toward the aft end of the airframe, giving it the appearance of a torpedo. Two short, narrow chord wings are positioned midway on the fuselage, with folding cruciform stabilizing surfaces in the rear. In flight, one wing is slightly higher than the other is, as the wings are mounted on a pivot point and then fold into slots in the fuselage for storage. Sea- and ground-launched versions are encased in a metal canister for storage and launch. Submarine-launched versions are housed in a shell capsule, which is fired from a standard torpedo tube. Approximately 10 meters (33 feet) from the launching submarine, the solid booster is ignited, and four jet tabs provide steering stabilization to the surface. The Tomahawk leaves the water at an angle of about 50 degrees, climbing under booster rocket power. Shortly thereafter, the plugs are ejected from the fuselage wing slots and a shroud that covers the booster/missile junction is blown off, at which time the tail surfaces spring out into place. At burnout, the booster is ejected and the wings extend. A retractable air intake drops into place, and the turbofan engine is automatically started, allowing the missile to continue in cruise mode.

	Metric	**U.S.**
Dimensions		
Length	555.00 cm	18.2 ft
Length w/booster	610.00 cm	20.0 ft
Diameter	52.73 cm	20.76 in
Weight	1,204.54 kg	2,650 lb
Weight w/booster	1,454.55 kg	3,200 lb
Wingspan	265.35 cm	8.70 ft

	Metric	U.S.
Performance		
Speed	885 kmph	477.86 knots
Altitude (cruise)	10-250 m	32.8-820.2 ft
Range (anti-ship)	465 km	251.08 nm
Range (nuclear)	2,500 km	1,349 nm
Range (conventional)	1,111.2 km	600 nm
Range (Block III) [(a)]	1,666.8 km	900 nm
CEP	7.62 m	25 ft

[(a)] With the Block III improvements, the range of the conventional land attack version will be increased to 900 nautical miles, while the dispenser version could either have a 100-nautical-mile-range increase or carry additional submunitions.

Propulsion. Originally, one Williams International F107-WR-103 turbofan engine, 4.5 kN (1,000 lbst) at sea level equipped with the Tomahawk. The Tomahawk is equipped with the F107-WR-400 engine, which was followed by the F107-WR-402.

The surface- and sea-launched versions have a Mk 106 solid-propellant booster rocket providing about 32.62 kN (7,250 lbst); they were manufactured by Atlantic Research Corporation/TRW Applied Technology Division (ARC has since been purchased by Aerojet). United Technologies' Chemical Systems Division was the other supplier for the Mk 106 Mod 0 booster. The booster weighs 157.73 kilograms (347 lb) and is 66 centimeters (26 in) long and 48.3 centimeters (19 in) in diameter. An increased thrust booster rocket motor was developed to provide the sub-launched Tomahawk with the 1,127.2-kilometer (700-mile) range of the surface- launched missile, the Mk 111. Initial Operating Capacity (IOC) of the improved booster was reached in 1987. The missile's F107 engine uses JP-9 fuel.

Control & Guidance. All U.S. strategic cruise missiles, including the strategic Tomahawk missiles, are equipped with the TAINS navigation package. The TAINS (TERCOM Assisted Inertial Navigation System) weighs 37 kilograms (81.4 lb). The U.S. Navy Tomahawk Land Attack Cruise Missile (TLAM) employs an inertial navigation system that is updated periodically by a DPW-23 TERCOM (Terrain Contour Matching navigation system) for the nuclear version (BGM-109A), and by TERCOM and DXQ-1 DSMAC (Digital Scene Matching Area Correlation system) for the conventional variants where more precision is desired (BGM-109C). The McDonnell Douglas (Boeing) DSW-15 guidance set consisted of a Litton Industries Guidance & Control Systems Division RMUC (Reference Measurement Unit Computer), a Honeywell radar altimeter from the APN-194 family, and other interface and power equipment. The RMUC comprises a four-gimbal P1000 inertial platform and the Litton 4516-C digital computer with 64K memory. Litton was awarded a contract to develop a successor system to its guidance unit that combines high-accuracy laser gyro sensors with a Global Positioning System (GPS) receiver in a single unit, designated LN-100G. Litton was later acquired by Northrop Grumman.

The BGM-109C Block I and Block IIA conventional versions with a Bullpup Unitary Warhead use the McDonnell Douglas (Boeing) or Loral (Northrop Grumman) DSMAC prior to engaging a single target, whereas the BGM-109C Block IIB submunition dispenser version uses the DSMAC prior to engaging each of multiple targets for improved accuracy at each location. The Tomahawk Anti-Ship Missile (BGM-109B TASM) employs a modified McDonnell Douglas (Boeing) Harpoon guidance set (DPW-23) comprising a Texas Instruments active radar seeker (which incorporates electronic countermeasures capabilities), an IBM digital computer with 64K memory, a Lear Siegler or a Northrop Grumman attitude reference assembly, and a Honeywell radar altimeter common with the land attack missiles. In addition to the Harpoon-common equipment, the TASM employs PI/DE (Passive Identification and Direction-Finding Equipment) to assist in identifying and attacking high-value enemy ships.

The U.S. Navy Block III upgrade of the TLAM conventional versions will add a GPS, an insensitive munition warhead, longer range, improved DSMAC, and TOA (time of arrival) control for increased operational effectiveness (see TLAM Block III entry). All Tomahawk OFS (operational flight software) was designed by McDonnell Douglas (Boeing). The TLAMs use a single OFS for the submarine- or surface ship-launched nuclear versions and another single OFS for the conventional variants. TASMs use a single OFS for submarine and ship launches.

Launcher Mode. For submarines, the missiles are launched from 54-centimeter (21.26-in) torpedo tubes or the external vertical launch system (VLS), the Mk 45 Capsule Launch System. Westinghouse Electric

Corporation, Marine Division, Sunnyvale, California, received its fourth and final contract for the Capsule Launching System in January 1990 (for the procurement of 54 units). Westinghouse has since been purchased by Northrop Grumman. Versions other than the Tomahawk Airfield Attack Missile are encased in a stainless steel canister during initial launch.

Surface warships are equipped with either the Armored Box Launcher System (ABLS) or the Mk 41 VLS. Unidynamics, St. Louis, Missouri, was selected on December 8, 1982, to provide the Tomahawk ABLS. The initial eight ABLSs were installed aboard the USS *Iowa* (BB-61). The Mk 41 VLS is manufactured by Lockheed Martin Corporation.

Warhead. Some of the U.S. Navy's BGM-109 inventory is fitted with a W80 Mod 0 nuclear warhead, developed by the Energy Research and Development Administration (now the Department of Energy), with a selectable yield estimate of 200 kT to 250 kT. The W80 Mod 0 warhead uses oralloy (enriched uranium) as the fissile base and supergrade plutonium for the fusion material; PBX-9502 insensitive high explosive is used as the high-explosive initiator. The BGM-109 ground-launched cruise missile has the W84 variable yield nuclear warhead, with yields selectable between 10 and 50 kT. The warhead's nuclear components are essentially the same as those of the W80.

The Tomahawk anti-ship and land attack missile carries a conventional 454.55-kilogram (1,000-lb) high-explosive warhead. The TLAM-C is fitted with the WDU-36B insensitive warhead as part of the Block III upgrade. The insensitive warhead, developed by the U.S. Naval Weapons Center, China Lake, California, degrades without exploding in the presence of heat and/or flame. The warhead also incorporates a programmable delay fuze. Further studies are being conducted on enhanced anti-ship warheads, which are designed to cause the ship to break in half. Two additional enhanced warheads/fuzing were under development for the AGM-109H. The Tactical Airfield Attack Munition (T-AAM), developed by Lawrence Livermore Laboratory, consists of a submunitions dispenser with 50 to 60 bomblets to destroy airfield runways and hardened bunkers. An earth-penetrating, kinetic energy warhead for anti-runway use is also under low-scale development.

The Tomahawk Block IV program (also known as Tomahawk Baseline Improvement Program, or TBIP) offered two different warhead options: the Tomahawk Multi-Mission Missile (TMMM), which will attack both land-based and seaborne targets; and the Tomahawk Hard Target Penetrator (THTP), which will be used by the WDU-36B high-explosive warhead developed by China Lake for the BGM-109C Block III missile. Raytheon (then Hughes) also proposed the Tomahawk Stop the Attacking Regiments (TSTAR), which added anti-armor smart submunitions such as BAT (Brilliant Anti-armor), the Sensor Fuzed Weapon (SFW), and the Wide Area Munition (WAM). The TSTAR would have been used against both fixed and moving targets, and was examined by the Joint Cruise Missile Office.

BGM-109 Tomahawk Cruise Missile

Source: U.S. Navy

Variants/Upgrades

A significant number of Tomahawk variants have been developed, although only a small number have actually entered production. Acronyms that have been used to refer to the Tomahawk include:

ALCM. Air-Launched Cruise Missile, usually referring to the Boeing AGM-86.

GLCM. Ground-Launched Cruise Missile, the U.S. Air Force's version of the BGM-109 for European theater nuclear support (BGM-109G).

MRASM. Medium-Range Air-to-Surface Missile, a joint USAF/USN project for a modest-cost weapon for use against high-value targets, also referred to as the Tomahawk II (service designations include AGM-109C/I/J for USN and AGM-109H for USAF).

SLCM. Sea-Launched Cruise Missile, which refers to all submarine- and surface ship-launched Tomahawks.

TAAM. Tomahawk Airfield Attack Missile, which refers to both the AGM-109H and the BGM-109F.

TALCM. Tomahawk Air-Launched Cruise Missile, which is in reference to the entire AGM-109 series.

The following provides a breakout by designation.

Designation	Type	Warhead	Remarks
BGM-109A	TLAM-N	W80-0 nuclear	Tomahawk Land Attack Missile - Nuclear
BGM-109B	TASM	454.55-kg high explosive	Tomahawk Anti-Ship Missile
BGM-109C	TLAM-C	454.55-kg high explosive	Tomahawk Land Attack Missile - Conventional
BGM-109D	TLAM-D	CBU-87/BLU-97/B	Tomahawk Land Attack Missile - Dispensing
BGM-109E	TASM	Reactive case high explosive	Tomahawk Anti-Ship Missile
BGM-109F	TAAM	Submunition dispensing	Tomahawk Airfield Attack Missile
BGM-109G	GLCM	W84 nuclear	Ground-Launched Cruise Missile
AGM-109C [(a)]	MRASM (Navy)	120-kg high explosive	Medium-Range Air-to-Surface Missile
AGM-109H [(a)]	MRASM(USAF)	BLU-106/B BKEP	Medium-Range Air-to-Surface Missile
AGM-109I [(a)]	TASM	120-kg high explosive	Tomahawk Anti-Ship Missile
AGM-109J [(a)]	MRASM (Navy)	Submunition dispensing	Medium-Range Air-to-Surface Missile
AGM-109L [(a)]	MRASM (Navy)	230-kg high explosive	Medium-Range Air-to-Surface Missile

[(a)] Terminated

The BGM-109C missiles were previously divided into two subvariants: the Block IIA missiles had the 454.55-kilogram (1,000-lb) semi-armor piercing Bullpup warhead, while the Block IIB missiles had the submunition-dispensing device (CBU-87) with the BLU-97/B Combined Effects Munition submunition. The Block IIA missiles are now designated BGM-109C, while the former Block IIB missiles are now designated BGM-109D.

During Operation Allied Force, the U.S. is said to have used a secret version of the Tomahawk, designated TLAM Block III D2. This missile is equipped with an electric attack submunition used to disrupt electrical operations. This variant was first used during Operation Desert Storm against Iraq's electric generation system. Two versions of this missile are said to exist: one dispenses an aluminum silica threat that is coated to make it highly conductive; the other uses a powder. When either lands outdoors at transformer and switching yards, the emergency short-circuiting equipment automatically shuts down.

Program Review

Background. The competitive development of the Tomahawk cruise missile began in 1972 when the U.S. Navy awarded study contracts to five firms. In January 1974, General Dynamics and Vought were selected as finalists in the competitive airframe development program. The Vought entry was designated YBGM-110, while General Dynamics' system was called YBGM-109. Beginning in July 1974, tests involving a wind tunnel, underwater launches, and boost to recovery were conducted with inert test vehicles.

In March 1976, the U.S. Navy announced that General Dynamics had been selected as prime contractor, and a $34.8 million contract was awarded. At that time, the name Tomahawk was formally applied to the BGM-109 by the U.S. Navy. Development moved ahead steadily, with the first Tomahawk flight completed successfully in March 1976, two months ahead of schedule. The first fully guided flight was accomplished in June 1976, four months ahead of schedule. In subsequent tests from 1976 to 1979, 40 Tomahawk flights were performed in

the course of the validation phase. Eighty-five percent of the vehicles fired were recovered by means of a parachute system, and following refurbishment, were reserved for future use. The validation phase included a demonstration of the system throughout its flight envelope, an underwater launch, booster operation, transition to flight, stabilization and glide, anti-ship search and acquisition, and attacks of at-sea targets. Guidance system accuracy was demonstrated to be about three times better than program goals.

Heavy Use of Tomahawk Missiles to Occur in Future Decades

The previous October (1975), the U.S. Naval Air Systems Command selected McDonnell Douglas to provide the submarine-launched cruise missile (SLCM) guidance system, after a 16-month competitive development phase that included captive flight tests, at-sea alignment tests, and shock, environmental, and other simulations. A Joint Cruise Missile Program Office (JCMPO), with the U.S. Navy as lead service, was set up in January 1977 to oversee development of the cruise missile programs. In October 1986, responsibility for the BGM-109G ground-launched cruise missile (GLCM) was moved entirely to the Air Force Aeronautical Systems Division, and the Joint Cruise Missile Program Office became known as the Cruise Missile Program Office. This new office encouraged second-source subsystem competitive procurement. The U.S. Navy Tomahawk made its first transition from boost flight to cruise flight on February 24, 1977. Earlier, in December 1976, the missile successfully demonstrated its long-range, over-the-horizon capability to search for and locate a target at sea. Following launch from an A-6 attack aircraft, the missile made a 302.74-kilometer (188-mile) low-level flight to find its target.

INF Treaty. The Intermediate-Range Nuclear Forces Treaty had only a marginal effect on the Tomahawk program, although it did eliminate the 464 BGM-109Gs from the U.S. inventory, along with their launchers and support facilities. The U.S. commenced the destruction of its GLCMs in 1988, with the sawing in half of an initial batch of 41 at Davis-Monthan Air Force Base in Arizona. The final GLCMs were withdrawn from Europe in March 1991.

Combat Operations. The Tomahawk was first used in combat during Operation Desert Storm (1990-1991). Some 291 Tomahawk Block II missiles (264 C and 27 D models) were fired during the 1991 war to eject Iraq from Kuwait. A further 23 missiles were fired in June 1993, to retaliate for the alleged involvement of the Iraqi government in an assassination plot against former President George Bush. In all, nearly 70 Tomahawks were fired in 1993, partly to compel Iraq to allow United Nations inspection of its nuclear, biological, and chemical installations.

In 1995, 13 Tomahawk Block III missiles were used against Bosnian Serb targets. The missiles struck Serb anti-aircraft positions and communication facilities after weather conditions made aircraft sorties inadvisable.

In 1996, the Tomahawk was again fired against Iraqi targets. Some 31 missiles were used against Iraqi air defense sites and command and control facilities in retaliation for Baghdad's attacks on dissident Kurdish forces.

In August 1998, the U.S. launched strikes against suspected terrorist camps in Afghanistan, and a Sudanese factory thought to be involved in the development and manufacture of chemical weapons. These attacks were in response to terrorist bombings of the U.S. embassies in Kenya and Tanzania. Approximately 79 missiles (13 at Sudan and 66 at Afghanistan) were launched from surface ships and submarines against these targets.

Operation Desert Fox was launched against Iraq in December 1998. The attacks were directed at eliminating Iraq's capacity to develop and produce weapons of mass destruction and ballistic missiles. Some 325 (some say 330) Tomahawks were fired during this operation. Of these, 10 were said not to have successfully transitioned to their cruise flight phase, but to have dropped into the sea.

In early 1999, the NATO Alliance commenced Operation Allied Force, which was aimed at evicting Serbian security forces from Kosovo province. A total of 238 Tomahawk Block IIIs were fired during the fighting: 218 by the United States and 20 by the United Kingdom. Some 29 were fired at mobile targets by the U.S. Navy: 19 Block IIICs and 10 Block IIIDs. According to reports, 20 of these missiles achieved mission success. The Tomahawk's overall success rate was 85 percent.

Enduring & Iraqi Freedom. In response to the September 11, 2001, terrorist attacks on the Pentagon and the World Trade Center, the United States launched Operation Enduring Freedom. The goal of this operation is the elimination of the al-Qaeda terrorist group, led by Osama bin Laden and widely believed to be responsible for the September 11 attacks. At the time, Bin Laden was believed to be in Afghanistan, being sheltered by the Taliban regime.

On October 7, the United States began the first phase of this operation with aerial attacks on targets inside Afghanistan at about 12:30 p.m. (Eastern Time). The

initial strikes included the firing of nearly 50 Tomahawk and other cruise missiles by the United States and the United Kingdom.

In 2003, the U.S. Navy fired 802 Tomahawk cruise missiles during Operation Iraqi Freedom, which resulted in the collapse of Saddam Hussein's regime.

Missile Models. The Tomahawk has been in production for some 15 years. This family includes land-based, shipborne, and air-launched versions. The following is information on the main production versions of the Tomahawk.

TLAM-C. The U.S. Navy developed two Tomahawk Land Attack versions: one equipped with a conventional unitary warhead, the other outfitted with a submunitions dispenser. The unitary warhead version of these missiles is known as the BGM-109D TLAM-C Block IIB, a modified BGM-109C.

The U.S. Navy completed four successful Tomahawk operational test launches from both surface vessels and submerged submarines in 1988. Previous failures had been attributed to a procedural error on the launching submarine, not a problem with the Tomahawk missile. The production version of the TLAM-C was equipped with a pop-up and terminal dive flight profile, the first of which was ready for deployment in March 1988. Initial plans announced in 1986 called for the procurement of 1,400 TLAM-Cs with the single 1,000-pound warhead. The TLAM-C reached Initial Operational Capability (IOC) in March 1986.

TLAM-D. In January 1984, the Convair Division of General Dynamics (now part of Raytheon) received a $30.8 million contract to develop a submunition dispenser for the TLAM-C version of Tomahawk (designated TLAM-Dispenser). The initial payload carried by the TLAM-D was the Aerojet's BLU-97/B multipurpose submunition, which is dispensed from the missile laterally.

The TLAM-D (submunition carrier) has successfully flown to and destroyed multiple targets during an 800-kilometer mission from a surface ship off the California coast to the China Lake Naval Weapons Center range. The TLAM-D entered U.S. inventory (IOC) in August 1988 – one month early.

TLAM Block III. The U.S. Navy developed an improvement package for the Tomahawk's TERCOM guidance system, which helped ease its dependence on terrain maps of areas over which the missile flies. This upgrade package, designated Block III, modified the digital scene-matching area correlator (designated DSMAC IIA) to function with less data, and provided engine enhancements, more flexible terminal guidance, and a time-of-arrival capability. The Naval Air Systems Command awarded separate contracts to General Dynamics Convair Division (now Hughes Missile Systems) and McDonnell Douglas Missile Systems Company (formerly Astronautics) in March 1988. A winner-take-all competition for the full-scale engineering development was planned for October 1988. McDonnell Douglas was selected as the winner of this competition. U.S. Navy plans called for procurement of these upgrade packages to commence during FY92.

The Block III improvements involve the installation of a NAVSTAR GPS receiver on the missile (both TLAM-C and TLAM-D). The GPS receiver will use the information processed through the NAVSTAR satellites to determine precisely the location and velocity of the missile. This will complement, or substitute for, Tomahawk's current en route navigation system, TERCOM, in which measurements by an onboard radar altimeter are compared with terrain maps stored in the missile.

Upgrade Provides Better Over-Water Performance

One problem with TERCOM is that it does not work over water (or certain desert terrain such as in Saudi Arabia). Rather, the missile uses inertial guidance until over land, and then relies on precise terrain maps of the land areas over which the missile is to fly. These maps are provided by the U.S. Defense Mapping Agency (DMA), but this agency has had trouble over the years keeping up with an ever-increasing demand from the U.S. military.

By relating the missile's position and velocity to the known position of its target, a GPS would eliminate the need for maps of en route areas. This would reduce the DMA's workload to mapping target areas to support the TLAM-C/D Digital Scene Matching Area Correlator (DSMAC) terminal guidance system.

The addition of the GPS is expected to increase the missile's standoff range by as much as 20 percent and to open up alternative routes to the target, enabling missiles to avoid engagements against land-based defenses. Since navigation over water will be more accurate, mission planners will be able to increase the range of Tomahawk attacks on small islands, and they will not have to use en route island overflights to reduce navigation errors. Mission planning will take less time. Other Block III upgrades include:

- DSMAC-IIA terminal guidance, which needs less data processing to create DSMAC scenes and offers greater operational flexibility. The system will be less sensitive to the diurnal and seasonal effects that

cause changes in the appearance of landscapes. The missile will also use a larger number of scenes for precision guidance, which will shorten mission-planning time and increase the strike options available.

- A capability to control the missile's time of arrival at specified en route points and at targets, improving coordination of strikes by Tomahawk missiles and carrier-based attack aircraft.
- Installation of an insensitive munition warhead, developed by the U.S. Naval Weapons Center. The warhead, designated WDU-36B Block II, weighs 184.1 kilograms (405 lb) and has a conical shape. The new warhead would replace the current WDU-25B Bullpup system.
- An improved engine, the Williams 402 turbofan, with 20 percent greater thrust and a 2 to 3 percent decrease in fuel consumption. Range is also enhanced as the missile's warhead weight has been reduced, allowing it to carry more fuel (up to 200 extra pounds). Although the engine is not part of the Block III package, it will be included in all Block III missiles. Rockwell International Collins' Government Avionics Division was selected in 1989 to supply the two-channel NAVSTAR Global Positioning System receiver for the Tomahawk Block III missile.

The U.S. Navy may produce what has tentatively been called a Block IIIA, which could involve the installation of a new booster, the Mk 111, for all submarine-launched Tomahawks. Also, a Block IIIA upgrade could include improvements developed under the Tomahawk Baseline Improvement Program (TBIP), although the U.S. is still considering just how it will go about enhancing its Tomahawk inventory (see Block IIIA and Block IV entries below).

TLAM Block IIIA. The U.S. Navy has studied the possible integration of certain aspects of the Block IV/TBIP upgrade into Block III missiles. Specifically, the service is examining the use of the Block IV's navigation subsystems. This study was prompted by the rising cost of the Block IV/TBIP program, and cuts in the U.S. Navy's budget.

The use of Block IV subsystems would almost double the Block III missile's shelf life, as well as ease missile depot maintenance requirements and create overall cost savings, according to service officials. The U.S. could incorporate certain Block IV reliability improvements into existing Block III missiles. However, the U.S. now appears to be considering the development of a Block IV Phase I and Phase II missile, or a nearly all-new missile called Tactical Tomahawk (see TLAM Block IV entry).

TLAM Block IV. Despite its success during Operation Desert Storm, certain Tomahawk shortcomings did become apparent. These shortcomings, along with the decision to terminate the Tomahawk's next-generation replacement and reductions in new unit buys, prompted the U.S. Navy to seriously consider additional upgrades for this system.

These upgrades were grouped under the designation Tomahawk Baseline Improvement Program (TBIP), also known as Tomahawk Block IV. Development began in 1994, but the program was eventually abandoned in favor of the new Tactical Tomahawk.

Tactical Tomahawk. See separate report titled Tactical Tomahawk.

Significant News

Chilean Navy Decides to Get Both Ship- and Air-Launched Harpoons – The Chilean Navy has decided to split its order for 20 Harpoon Block II anti-ship missiles into two different versions of the anti-ship missile. The Navy's original $45 million order, announced in 2005, was for all 20 to be of the ship-based RGM-84 version. That order has now been divided into 10 ship-based RGM-84s and 10 air-launched AGM-84s.

The air-launched version is specifically destined for the service's four P-3 maritime surveillance aircraft, which have lacked an attack capability. The Harpoons could also be fitted to the ex-U.S. Navy S-3 Viking ASW aircraft now being offered to Chile by the U.S., of which the Chilean Navy is looking at possibly acquiring four. The Harpoons could also be fitted to the Chilean Air Force's new F-16C/D fighters.

The acquisition of the air-launched version of the Harpoon represents a significant upgrade in Chile's strategic strike capability, since the Harpoon can be used as a mini-cruise missile. However, this also raises questions as to how other nations in the region will react, and whether they will, in response, acquire comparable weapons. (*El Mercurio*, 9/06)

Lockheed Martin Offers Missile for U.K. SPEAR Need – Among the candidates to meet the United Kingdom's new strike missile requirement is Lockheed Martin's Surveilling Miniature Attack Cruise Missile

(SMACM). Lockheed Martin Missiles and Fire Control is offering this system to fill the U.K.'s Selected Precision Effects At Range (SPEAR) need.

The SPEAR project is scheduled to achieve "initial gate" in the first quarter of 2006. A "main gate" approval is planned for 2010. The SPEAR could achieve an initial operational capability by 2013.

Development of the SMACM was set aside to allow Lockheed Martin to focus its energies on the U.S. Air Force's Small Diameter Bomb Increment II contest. Lockheed Martin, along with teammate Boeing, is competing with Raytheon for this USAF contract. (*Flight International*, 9/06)

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Funding

The U.S. Navy has ceased procurement of the Tomahawk Block III. Future funding is being directed toward the acquisition of the new Tactical Tomahawk cruise missile. Production of all-new Tomahawk Block IIIs ceased in FY99.

Prior to 2001, the U.S. was remanufacturing older Tomahawks in order to bring them up to Block III status. Some 324 Block IIDs, 100 Block ICs, and 200 Block I TASMs were being brought up to Block III status. The U.S. Navy received $442.4 million to remanufacture these missiles.

The U.S. Navy received $350 million in the FY02 Defense Emergency Response Funding (DERF) and $598 million in FY03 Cost Of War (COW) funding to remanufacture a further 784 Tomahawk missiles.

SLCM PROCUREMENT HISTORY[(a)]

Fiscal Year	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94
TASM	3	25	24	31	12	90	97	120	80	75	21	0	0	0	0
TLAMs															
Nuclear	0	0	4	32	112	70	99	97	19	10	0	32	0	0	0
Conv.	3	25	20	0	0	20	53	96	304	333	278	81	76	100	126
Dispenser	0	0	0	0	0	0	0	11	72	92	101	287	100	100	90
Subtotal	3	25	24	32	112	90	152	204	395	435	379	400	176	200	216
Total	6	50	48	63	124	180	249	324	475	510	400	400	176	200	216

[(a)] Breakout for the TLAM variants shows estimates. FY91 figures do not include the 278-unit supplemental buy. No breakout between the TLAM-C and TLAM-D has been provided for the supplemental buy. Purchases after 1993 are for the TLAM version only. Procurement for FY95 was 274 units; for FY96, 107 missiles; and for FY97, 155 missiles.

Contracts/Orders & Options

In February 2002, Raytheon received a $29.7 million modification contract for the remanufacture of 22 Tomahawk missiles to Block IIIC configuration for the United Kingdom. Work was completed by September 2004. Contract Number N00019-00-D-0275

Timetable

Month	Year	Major Development
	1979-80	Competitive fly-off
		Boeing awarded ALCM contract
		General Dynamics awarded MRASM contract and enters FSED
	1981-82	Flight evaluations completed on SLCM variant
		Low-rate production of SLCM and GLCM variants; SLCM Initial Operational Capability
Mid	1983	MRASM canceled
Oct	1983	McDonnell Douglas opens Tomahawk facility
Dec	1983	GLCM Initial Operational Capability

AGM-109/BGM-109 Tomahawk

Month	Year	Major Development
Jun	1984	BGM-109A operational with U.S. Navy
Jun	1985	First vertical launch test
Nov	1985	First test flight of submunition dispensing variant
	1987	Full-scale production of all variants
	1987	INF Treaty signed, expected to eliminate all GLCMs
	1988[(a)]	Vertical launch capability for Tomahawk SLCM
Aug	1988	BGM-109D submunition-dispensing missile achieves IOC – one month early
	1991	Tomahawk used in combat against Iraq
	1994	Hughes selected as sole Tomahawk contractor
Dec	1998	Operation Desert Fox launched against Iraq
	1999	Operation Allied Force launched against Yugoslavia
	1999	U.S. to remanufacture additional Tomahawks, raising total to 624 units
	2002	Block III procurement extended
	2003	Tomahawk Block III used during Operation Iraqi Freedom
Dec	2005	Block III test fired off California coast
Jun	2006	Destroyer launches Tomahawk cruise missile off California coast
		Submarine fired Block III missile off Florida coast
Aug	2006	Destroyer launches Block III missile off California coast

[(a)] Estimate

Worldwide Distribution/Inventories

User Countries. The **United States Navy** remained the exclusive operator of the Tomahawk missile system through 1998. The **United Kingdom** will become the first overseas nation to deploy the Tomahawk. The U.S. Army's inventory of BGM-109G Gryphon land-based nuclear missiles was withdrawn from service due to the Intermediate-Range Nuclear Forces (INF) Treaty with the former Soviet Union.

Forecast Rationale

The Tomahawk cruise missile made its combat debut during Operation Desert Storm. Not since the Second World War had any military used long-range strike missiles in such large numbers. The U.S. expended 802 Tomahawk missiles during the fighting to eject Iraq from Kuwait.

No further purchases of the Tomahawk Block III will take place. The United States is focusing its procurement funding on the new Block IV version, also known as the BGM-109E Tactical Tomahawk. This missile was not operational for use in Operation Iraqi Freedom, but will be available to participate in any future conflicts.

The BGM-109 Tomahawk Block III cruise missile will remain in U.S. service for an extended period. The Block III is still a highly effective weapon and additional upgrades are likely.

Like the United States, the United Kingdom, the only foreign operator of the Tomahawk, will not place any additional orders for the Tomahawk Block III. Instead, potential foreign customers for U.S.-built cruise missiles will opt for the Tactical Tomahawk.

Even as Tactical Tomahawk production is ramped up, the U.S. Navy is examining new strike missiles to fill the gap between the Tactical Tomahawk and less expensive (and shorter range) precision-guided munitions and naval guns. Options being studied include the Affordable Weapons System (AWS), which is being developed by Titan Corporation. For further information on these new naval strike systems, please see the separate NSFS report in Forecast International's *Missile Forecast* binder.

***Notes**: Our forecast lines for the BGM-109A TLAM-N, BGM-109B/E TASM, BGM-109C TLAM-C, BGM-109D/F TLAM-D and BGM-109G GLCM include RDT&E/FOT&E missiles. The BGM-109C/D line represents a combination of new and remanufactured units and includes Block III missiles.*

Ten-Year Outlook

ESTIMATED CALENDAR YEAR PRODUCTION

			High Confidence Level				Good Confidence Level			Speculative			
Missile	**(Engine)**	**thru 06**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**Total 07-16**
RAYTHEON COMPANY													
BGM-109A	F107-WR-400	509	0	0	0	0	0	0	0	0	0	0	0
BGM-109B/E	F107-WR-400	577	0	0	0	0	0	0	0	0	0	0	0
BGM-109C	F107-WR-400/402	1445	0	0	0	0	0	0	0	0	0	0	0
BGM-109C/D	F107-WR-402	2623	0	0	0	0	0	0	0	0	0	0	0
BGM-109D/F	F107-WR-400/402	957	0	0	0	0	0	0	0	0	0	0	0
BGM-109G	F107-WR-103	525	0	0	0	0	0	0	0	0	0	0	0
Total Production		6636	0	0	0	0	0	0	0	0	0	0	0