# ARCHIVED REPORT

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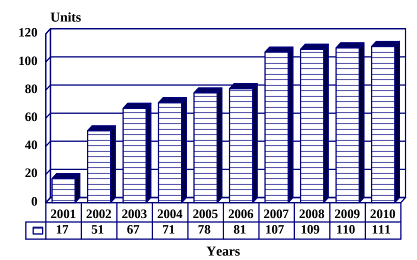
# Advanced Anti-Ship Missile – Archived 6/2002

## Outlook

- Concept studies
- The US has yet to initiate any formal development program
- To meet short-term needs, the US Navy could procure the Harpoon Block II. This missile has already been ordered by Denmark and Taiwan
- A true next-generation anti-ship missile will probably not be available until 2010 or later
- The graph to the right represents Harpoon Block II production

10 Year Unit Production Forecast
2001 - 2010




## Orientation

**Description.** Next-generation advanced anti-ship missile.

**Sponsor.** The US Department of Defense through the US Navy's Naval Sea Systems Command and almost certainly supported by the Defense Advanced Research Projects Agency (DARPA).

**Contractors.** No specific prime contractor has been selected. The US will contract with Boeing for the Harpoon Block II.

**Status.** Believed to be in the feasibility design study state. Some prototype component development and testing may be under way. No specific next-generation anti-ship missile development program is known to be under way.

**Total Produced.** Full-scale production has not commenced.

**Application.** Developed as a long-range, possibly supersonic, anti-ship missile to counter advancement in surface warfare capabilities. This program could provide a follow-on to the AGM/RGM/UGM-84 Harpoon.

**Price Range.** Our estimates have placed the price of this system at approximately $2,900,000 per unit. This price is expected to decrease somewhat as the program continues.

## Technical Data

**Design Features.** Due to the secrecy surrounding any current next-generation anti-ship missile development program, little technical information is available at this time. The new missile's airframe could take advantage of advances in stealth technology, applied through the use of composite materials and the incorporation of radar-absorbent coatings. The system could also make use of some of the design techniques developed for the AGM-129 Advanced Cruise Missile (ACM) program (see separate report).

The missile could use a turbojet, a ramjet or some hybrid (solid rocket motor, ramjet or turbojet combination) propulsion system. The missile may be equipped with a boost-glide-boost mode in order to reduce its overall infrared signature. A boost-glide-boost capability would enable the missile to close with the target without giving off a large infrared signature, since the main ramjet propulsion would not be ignited until the system is within a specified distance of the target. After detection, either by visual, infrared, or radar means, the missile's proximity to the target, combined with its supersonic speed, would allow the vessel's defensive systems only a minimum of time to react. Although suppressing the infrared signature of a ramjet is virtually impossible, detecting incoming missiles at long range is far more easily accomplished through the use of radar than infrared surveillance equipment.

Depending on the type of propulsion system and advanced in-fuel technology used, it is possible to achieve longer range than is offered by the current US inventory of anti-ship missiles.

Besides a new propulsion system, a next-generation anti-ship missile could be equipped with a global positioning system (GPS) receiver and an advanced inertial navigation system (INS). The missile may also make use of a Laser Radar (LADAR) guidance system (see separate Advanced Technology Cruise Missile report), as well as imaging infrared and millimeter wave technology.

This next-generation anti-ship missile system will be capable of being launched from airborne and surface-based platforms, including land-based vehicles, warships and submarines. The warhead is expected to be of a high explosive blast/fragmentation type.

Harpoon

Source: Boeing

## Variants/Upgrades

No specific variants or upgrades have been proposed as the system is still in the very preliminary stages of its development. If production is commenced, this missile will likely see a number of modification programs initiated to maintain its combat viability.

## Program Review

**Background.** In the 1980s, the US Department of Defense (DoD) began to consider possible successors to its inventory of Harpoon anti-ship missiles. A motivating factor was the anticipated introduction of the supersonic ANS (Anti-Navires Supersonique) and ANL (Anti-Navires Leger) anti-ship missiles which were expected to make the current generation of subsonic anti-ship missiles obsolete. Furthermore, the US DoD surmised that the defenses against anti-ship missiles would be modified and improved to counter the new supersonic threats. However, problems in the supersonic missile's development effort and ever lengthening delays in the proposed introduction date, as well as the collapse of the Soviet Union and Warsaw Pact alliance, diminished the urgency that the United States once felt for fielding a next-generation anti-ship missile. Research into the development of a next-generation anti-ship missile is proceeding, but at a fairly slow pace.

**Missile Projects.** The United States is conducting various studies of future missile technologies that could be applicable to the next-generation anti-ship missile. The projects range from a further enhanced Harpoon to all new, low-cost, long-range strike missiles that could reach hypersonic speeds. Among these latter projects are Affordable Rapid Response Missile Demonstrator (ARRMD), Cheap Shot, Fasthawk, HiSSM and Jump Start.

Harpoon Block II. To meet future US requirements, Boeing is offering a further upgraded version of its anti-ship missiles. Originally known as Harpoon 2000 but now called Harpoon Block II, this program is intended to modify Block ICs and IGs to provide a dual-role capability (anti-ship and land-attack) and better performance in a littoral warfare environment. The upgrade also would add another 15 to 20 years to the missile's life. Specifically, the US Navy would like the Harpoon to be more capable of engaging hostile warships in close proximity to other surface vessels (hostile, friendly or neutral), and man-made obstacles in the littoral (oil platforms, navigation buoys with radar reflectors, etc.) and near land (including islands) environments.

The Harpoon Block II is intended to improve the guidance accuracy of the missile by using the inertial navigation system (INS) and global positioning system (GPS) receiver/processor from the SLAM-ER. This would replace the current strap-down gyro with a ring laser gyro. The existing radar seeker signal processor would be modified to provide improved electronic counter-countermeasures, as well as target discrimination capability (blocking out land returns, for easier use in littoral warfare). Additional improvements considered include a datalink, vertical launch capability and a new seeker. The latter need could be fulfilled by updating the current Raytheon Texas Instruments' active radar seeker, although the US Navy is considering the procurement of an all new seeker. The integration of the Harpoon Block II with the Mk 41 VLS would require an additional booster motor and thrust-vector control, plus software changes to facilitate transition and reference. The missile could carry the existing 225 kilogram warhead or an optional submunitions dispenser.

The Harpoon Block II has three modes of operation:

- Q*uick reaction mode,* which replicates current Harpoon operation, utilizing heading reference navigation and optimal target search procedures provided by the command launch system;

- A*utonomous mode,* utilizing guidance and seeker signal processing improvements to permit GPS/INS guidance to the target area, land blanking/discrimination, and target track correlation/selection; and

- T*arget update/selection mode,* which uses the weapon datalink in order to transmit mid-course target updates to the weapon with an option to receive real-time seeker maps permitting operator selection of the target.

In late 1998, the US Navy approved a Harpoon Block II engineering and manufacturing development phase, but with Boeing picking up the majority of the cost. Flight tests will be concluded by mid 2001 with deliveries of all-new missiles and retrofit kits commencing in January 2002.

The service designations Block IJ and Block IX have emerged, although the former is likely to apply to the initial upgrade package. The price for the improved Harpoon could fall in the $75,000 to $250,000 range.

In April 1998, the US gave Boeing approval to export the Block II missile. Boeing believes that a potential market exists for 1,000 new missiles and 1,500 retrofit kits. Australia may be interested in joining this program. Also, Boeing has approached South Korea with a proposal to upgrade its Harpoon inventory to Block II status. Denmark agreed to procure the Block II missiles in December 1998. Deliveries to the Danish Navy could commence in 2002. Denmark already has the Block IG version in service. Taiwan could have the RGM-84L in service before the end of this year (2001).

Boeing is already thinking beyond the Block II to a Harpoon Block III. The Block III would include an enhanced seeker, vertical launch system compatibility, improved guidance and extended range.

ARRMD. DARPA is also studying the development of a hypersonic missile under the Affordable Rapid Response Missile Demonstrator (ARRMD) effort. This project aims to produce about 3,000 hypersonic missiles with a per unit cost of $200,000, capable of carrying a payload of 250 pounds over a distance of 400 nautical miles. The missile is to be air-launchable from tactical fighters and strategic bomber aircraft, and may be integrated with the US Navy's shipborne Mk 41 VLS.

DARPA commenced missile concept development in 1998 by awarding a $10 million, 18-month contract to Boeing. This portion of the ARRMD effort will involve the definition of manufacturing process and the flight test plan, the demonstration of propulsion-integrated flowpath and manufacturability, the preparation of an affordability assessment, and execution of a mission assessment.

Two ARRMD air vehicle concepts were being studied. Both were designed to deliver a 250-pound payload within about 30 feet of the target by employing an INS/GPS (inertial navigation system/Global Positioning System) guidance system that Boeing had developed for the Joint Direct Attack Munition. The vehicles differ, however, in their airframe and propulsion approaches.

One vehicle has a long, wide, flat shape, which will allow it to ride on its own shock wave for reduced drag. This waverider concept will be propelled by a supersonic ramjet (scramjet) engine currently being developed by Pratt & Whitney for the US Air Force.

The other vehicle has a more traditional cylindrical shape. It will use a dual-combustion ram/scramjet engine originally developed by Johns Hopkins University Applied Physics Laboratory for the US Navy but now being adapted for ARRMD by Aerojet.

Both propulsion concepts employ one or more solid rocket boosters to accelerate the missile to the ram/scramjet engine take-over speed.

Development work on these two ARRMD concepts was performed by an integrated team working from the following facilities:

- Boeing's Phantom Works, Seal Beach, California, St. Louis, Missouri, and Duluth, Georgia;
- Aerojet Sacramento, California; and
- Pratt & Whitney, West Palm Beach, Florida, and San Jose, California.

In late 1999, the US Air Force announced that it had settled on development of the "waverider" vehicle.

If the team is successful in meeting ARRMD performance and affordability objectives under this phase of the contract, DARPA will move ahead with a 30-month producibility and flight test demonstration effort. This phase could be worth upwards of $30 to $40 million.

According to Boeing, if all goes well with the ARRMD program and an engineering and manufacturing effort is launched by 2004 or 2005, the United States could have a hypersonic missile ready for deployment around 2010. Both the US Navy and Air Force could field a future hypersonic missile.

Cheap Shot. Plans by the US Navy to develop a new precision strike cruise missile came to light in early 1995. The missile, known as Cheap Shot, was envisioned as a low-cost alternative to the service's Tomahawk with a unit price in the area of $180,000 each. The Cheap Shot was to have a range capability of 700 nautical miles carrying a 700-pound warhead. Maximum capable speed may reach higher than Mach 3.

Cheap Shot development work was to be carried out under an Advanced Technology Demonstration (ATD) program beginning in FY97. The US Navy had supposedly set aside $14.9 million for this program, $4.3 million of which would be spent in Fiscal Year 1997. Cheap Shot would provide a low-cost delivery vehicle capable of carrying various submunitions. To achieve its low unit price, the Cheap Shot would use an axisymmetric body without aerodynamic surface and made of either rolled steel or aluminum, and be equipped with a thrust vector control joint in the front of the propulsion unit, thereby reducing the cooling requirement, component stresses, actuator loads, and erosion/corrosion of actuation/joint. The missile was also to use off-the-shelf components, including a GPS (global positioning system)/IMU (inertial measurement units) guidance system, an Mk 82 warhead, and existing universal joint/linear actuators. If all had gone well, Cheap Shot fabrication and flight tests would have occurred in FY99.

However, it appears that the US Navy has moved on from this concept to the new Fasthawk effort (see separate entry).

Fasthawk. The US Navy is considering possible replacements for Tomahawk, including a missile known as Fasthawk, a new proposal from Rockwell International (now part of Boeing). Fasthawk would offer a more accurate missile with a higher maximum speed (in excess of Mach 4) and at a lower price, somewhere around $280,000 without payload. Existing guidance technology would be used to keep the missile's per unit price down.

The Fasthawk would have a low radar cross-section and a wingless body – a necessity due to its anticipated high rate of speed. The airframe would be annular and would bend at a joint to allow it to change direction in flight.

A ramjet propulsion system could be used and the Fasthawk could offer a range of warhead options. Range and warhead configurations include: a 340-kilogram warhead with a range of 700 miles; 225-kilogram warhead with a 1,000 mile range; and 450-kilogram warhead with a 500 mile range. Total missile weight with a 340-kilogram warhead is estimated at 890 kilograms.

Fasthawk is a technology demonstration program, which is being evaluated under the Low Cost Missile System designation. At the end of a three-year demonstration effort, the US Navy will be in a position to determine if the concept warrants further work. This missile could include new propulsion and airframe technologies. The objective per unit price of the Fasthawk is about $280,000, although this does not include payload.

Technology from Fasthawk could be used in DARPA's Affordable Rapid Response Missile Demonstrator (ARRMD) project or to help the US Navy develop a family of missiles as part of the High Speed Strike Missile (HiSSM) effort. The US Navy and Air Force are considering a joint hypersonic missile program.

HiSSM. The High Speed Strike Missile project is envisioned as providing a family of air- and ship-launchable cruise missiles. This missile would enter service around 2010 and would complement the JSOW.

The air-launched HiSSM version would have a range of 100 to 500 nautical miles, fly at speed near Mach 4, and weigh 1,000 pounds. The missile would be compatible with US Navy and Air Force tactical fighter aircraft, including the internal launch bay of the F-22 Raptor.

The shipborne HiSSM version would have a range in excess of 700 nautical miles, weigh 3,400 pounds, and fly at speeds above Mach 6. The missile would be capable with the US Navy's Mk 41 Vertical Launch System (VLS) and similar submarine vertical launch systems.

Jump Start. The US Air Force is exploring the development of a hypersonic cruise missile which could reach speeds as high as Mach 8. The intended range objective is 750 miles. One system, called Jump Start, is being examined as part of the service's Hypersonic Technology (HyTech) Program, the USAF's only hypersonic missile technology development program.

The US Air Force did request $19.9 million in FY96 for generic technology in propulsion materials and propulsion, but it had no specific intention of developing a hypersonic cruise missile. At the time, due to budget constraints, the service was reluctant to become involved in yet another new missile development program.

The US Air Force's Science and Technology Board of the National Research Council reviewed the HyTech program in 1998. The group's report, titled "Review and Evaluation of the Air Force Hypersonic Technology Program," concluded that a hypersonic missile could not be deployed before 2015.

The report found that the US Air Force lacks the infrastructure to support such a development and the defined operational requirements that would allow research to go forward. The US will need to develop several critical enabling technologies before realization of an operational hypersonic missile can be expected.

Hurdles to the development of a hypersonic missile before 2015 are as follows:

- The HyTech program includes only limited ground testing of propulsion systems, leaving out flight testing to ensure engine reliability and durability of an integrated system;
- The program does not include critical technologies like fuel systems, cooling systems, guidance and control systems, integration, and warhead development;
- HyTech, if expanded to include a full-scale flight test program, could produce an operational system by 2015, but only if an integrated, supported System Program Office were established;
- The US Air Force has not laid out concrete operational requirements or conducted any study of the trade-offs involved in hypersonic development;
- The higher the speed of the missile, the higher the risks involved. The USAF, without set parameters, may be increasing complexity by pushing the speed of the missile beyond what is needed;
- Existing ground test facilities support testing only up to Mach 7. The US Air Force will have to develop additional computational test and range facilities to deal with hypersonic weapons.

Another source, one not involved in this study, cautions that, to make larger hypersonic vehicles viable, a breakthrough in advanced, high-energy, high-density fuels is very important.

If the US Air Force moved ahead with prototype development, it would require around three years and $300 to $400 million by some estimates. The actual unit price of the missile is projected at under $1 million.

## Funding

The United States has no specific line for the development of a next-generation anti-ship missile. Funding for technology applicable to future US hypersonic missile development efforts is contained within a variety of program elements and project numbers, but mostly falls under PE#0602702E Tactical Technology effort.

**US FUNDING**

| | FY98 | | FY99 | | FY2000 | | FY2001 | |
|---|---|---|---|---|---|---|---|---|
| | QTY | AMT | QTY | AMT | QTY | AMT | QTY | AMT |
| RDT&E | | | | | | | | |
| Proj - 1 | - | 6.6 | - | 10.7 | - | 12.4 | - | 4.2 |

All $ are in millions.

**Proj-1** PE#0602702F Tactical Technology, TT-06 Advanced Tactical Technology.

## Recent Contracts

No information is available.

## Timetable

| **Year** | **Major Development** |
|---|---|
| 1980s | Requirement for advanced anti-ship missile realized |
| 1997 | No specific Harpoon replacement selected |
| 1999-2002[a] | US to announce Harpoon Block II buy |
| 2000s[a] | Research into an Advanced Anti-Ship Missile continuing |
| 2000s[a] | Next-generation anti-ship missile development program to be launched |
| 2008-10[a] | Next-generation anti-ship missile ready to enter service |

[a] estimated

## Worldwide Distribution

The US may eventually export this new anti-ship missile, but any near-term production will be dedicated to US military needs.

**User Country(s).** The **United States** would be the first user of any next-generation anti-ship missile developed by its defense industry.

## Forecast Rationale

The United States does not seem to be in a hurry to replace its venerable Harpoon anti-ship missile. The Harpoon has met the US anti-shipping need for over two decades and is expected to continue to do so for a third. Still, there are options open to the United States for meeting its long-term anti-shipping requirements, including procuring the Boeing Harpoon Block II or developing an all new, possibly supersonic missile.

While development of an all-new missile is said to be very enticing to the US Navy, it may be beyond the services' foreseeable budgets. Furthermore, the acquisition of a next-generation anti-ship missile is not presently a high priority for the US Navy.

Financially, the Harpoon Block II is seen as a much more reasonable option, at least in the short-term. Although it has announced no specific plan, the US Navy may yet procure the Harpoon Block II, as it seems to be the best way of upgrading the US Navy's anti-shipping capability in the near term without incurring significant costs.

Beyond the US market, Boeing sees considerable demand potential for Block IIs due to the rise in operations within the littoral warfare environment. In addition to being able to more accurately hit surface warships, the Block II will be capable of striking coastal defense units, ships in port, radar and missile sites, fuel storage facilities and other valued assets. With this in mind, Boeing is marketing the Block II missile as a "poor man's" Tomahawk. The company is very much aware of the growing worldwide interest in stand-off weapons, as well as dual capable systems. This land attack capability could help to further stimulate sales.

Further upgrades to the Harpoon can only be performed for a limited amount of time before the point of diminishing returns is reached. Eventually, the US will initiate an all-new missile development program. The US is conducting research applicable to the development of a next-generation anti-ship missile including supersonic and hypersonic propulsion systems. Nevertheless, such a development effort, even if launched immediately, would not produce an operational missile until 2006 at the earliest.

## Ten-Year Outlook

**ESTIMATED CALENDAR YEAR PRODUCTION**

| | | | High Confidence Level | | | Good Confidence Level | | | Speculative | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Missile** | **(Engine)** | **thru 00** | **01** | **02** | **03** | **04** | **05** | **06** | **07** | **08** | **09** | **10** | **Total 01-10** |
| BOEING (Licensee) | | | | | | | | | | | | | |
| HARPOON BLOCK II | UNSPECIFIED | 0 | 17 | 51 | 67 | 71 | 78 | 81 | 107 | 109 | 110 | 111 | 802 |
| Total Production | | 0 | 17 | 51 | 67 | 71 | 78 | 81 | 107 | 109 | 110 | 111 | 802 |