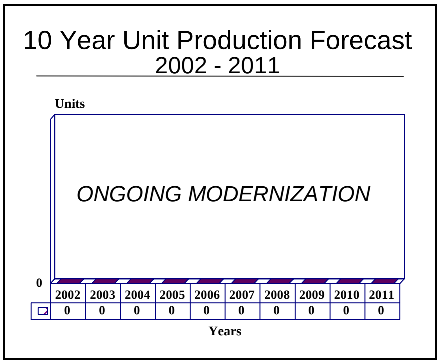
Phalanx Mk 15 CIWS - Archived 2/2003

Outlook

- Phalanx installations continue on new-production warships
- Roughly 900 systems built; 630 are on warships in service
- Balance form pool of spares for replacement and can be upgraded to fill future requirements
- Anti-surface mode will be of growing significance
- Support and maintenance market will extend for many years



Orientation

Description. A rapid-fire terminal or close-in weapon system (CIWS) with computer-controlled radar and gun.

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Licensees. No production licenses have been granted.

Status. In service.

Total Produced. More than 900 units had been procured by the end of 1999. Of these, approximately 630 are installed on ships currently in service.

Application. Phalanx was originally intended to defeat hostile aircraft and anti-ship missiles, other air threats that penetrate through area and longer range point defense systems, and low-speed flying aerial targets such as helicopters, terrorist aircraft, and unmanned aerial vehicles (UAVs). More recently, Phalanx has been modified to provide a defensive capability against surface threats, including small high-speed surface craft.

Platform. The Phalanx Mk 15 CIWS can be installed on ships ranging from fast-attack craft and OPVs to aircraft carriers.

Price Range. Unit cost including integration was US$5.4 million in FY94 (the weapon itself cost about US$3.3 million in FY90). Prior British procurement cost, presumably indicative of export prices, had suggested a US$8.8 million unit cost. However, the most recent British contract, for two systems at US$25 million, would suggest a US$12.5 million export unit cost.

Technical Data

	Metric	US
Specifications		
Caliber	20 mm	53 (0.787 in)
Rate of Fire	Dual fire rate, 3,000 or 4,500 rpm	
Muzzle Velocity	1,112 mps	3,650 fps
Maximum Range	5,500 m	6,000 yd
Effective Range	1,500 m	1,625 yd
Training Rate	126 °/sec	
Elevation Rate	92 °/sec	
Elevation/Depression	+85°/-25°	
Weight (above-deck)	5,454 kg	13,000 lb
Weight (below-deck)	212 kg	466 lb
Working Radius	5.5 m	18 ft

Design Features. The Mk 15 Phalanx close-in weapon system (CIWS) was originally designed so that it could also be tasked with engaging surface targets designated by conventional optical target designators. However, that configuration was officially discouraged, ships being expected to use dedicated light guns, such as single 20 mm or 25 mm Bushmasters, for self-defense against small surface craft. In recent years, the anti-surface role of Phalanx has been re-emphasized.

The Phalanx concept is the standard US Navy close-in weapon system, using bursts of armor-piercing ammunition to disable incoming anti-ship missiles. The weapon system's designation includes the mount plus integrated radar; the mount itself is designated Mk 72. The system's defensive capability is based on closed-loop spotting, which was considered a breakthrough in radar technology when first introduced. In that technique, advanced radar and computer technology is used to locate, identify, and direct a stream of armor-piercing projectiles to the target.

Phalanx combines an electrically controlled, pneumatically driven 20 mm six-barrel M-61A1 Vulcan automatic cannon of Gatling type, with a K-band digital MTI search radar and a K-band pulse Doppler monopulse track radar with a transmitter. In the latest, the Block 1B version, an electro-optical (EO) sensor is also included in the package, consisting of a forward-looking infrared (FLIR) imaging system that is linked to an automatic ACQ tracker. The operating wavelength of the FLIR is 8-12 microns.

All are mounted in a single, above-deck structure that requires a minimum of interface with other ships' systems. The gun barrel is installed on top of the magazine, while the system is topped by a characteristic semiround dome which encloses the radar antennas. The new FLIR and video tracker attachments are mounted on the side of this radar pod.

There are six major subassemblies: the radar-servo assembly, gun assembly, mount and train drive platform, barbette equipment assembly, electronics enclosure, and two control panels.

Initially, the projectiles used featured a core of depleted uranium, a very dense material that can penetrate the entire forebody of an incoming missile, causing a warhead reaction that leads to either a deflagration or detonation. Today only tungsten is used, primarily because the price of tungsten fell drastically in the late 1980s. Furthermore, tungsten's penetration capability against missiles and their guidance systems was found to be greater than that of uranium.

Operational Characteristics. For operation, the system has an electric power requirement for 3-phase 440 volts/ 60 Hertz, consuming 18 kW in search mode and 70 kW in track mode.

The weapon system's radar automatically detects and tracks incoming missiles. In the search mode, the radar uses unambiguous Doppler/ambiguous range, switching PRF to achieve range resolution in four range-coverage zones. During target acquisition, the system again uses unambiguous Doppler/ambiguous range and a derived search range, bearing, and speed to search a basket provided by the search radar. Normally, there is no operator intervention; the system decides autonomously whether to engage, although the operator can override this decision.

Some indication of Phalanx's performance is given by characteristics as projected in 1971. At that time, Phalanx evaluated targets it detected in terms of range, range rate, and sector. It scanned between 0 and 5 degrees in elevation (external designation was needed for any target at a higher elevation). It was expected to detect a target at 5,600 yards, acquire it at 4,300, and open fire at 2,500 (giving a first potential intercept at 1,000). The inner boundary (keep-out zone) was defined as 100 to 230 yards. The closed-loop spotter tracked the centroid of six projectiles at a time. The slewing rate was 1.75 rad/sec (100.3 deg/sec) with an acceleration rate of 10.5 rad/sec^2 (601.7 deg/sec^2).

The effective firing range is 1,486 meters (1,625 yards). The elevation and depression limits are -30 degrees to +85 degrees. The system's reaction time is three seconds, and the rate of fire was initially quoted at 3,000 rounds per minute, but was subsequently upgraded to 4,500 rpm with the introduction of the pneumatic gun drive in Baseline 1.

When the gun begins firing, the radar also tracks outgoing bursts of fire, predicts their point of closest approach to the incoming target, and corrects the aim of the following burst(s). This electronic spotting uses variable PRF with selected spectral frequency line tracking to measure the projectile stream's angular error. The manufacturer claims that this closed-loop spotting system improves lethality by as much as an order of magnitude. This self-contained fire control system was originally designated Mk 90, although that designation has since been dropped in favor of the Mk 15 designation embracing the entire system.

Some difficulties were encountered in service, however. Block 0 guns suffered from sea corrosion, a problem corrected by construction of special maintenance shelters around parts of the mount. The reload time of the ammunition drum, between 10 and 30 minutes, has been considered long. Larger capacity drums were later suggested to counter this particular criticism, however. The earliest systems had magazines holding 900 rounds, while newer systems have magazines housing up to 1,550 rounds.

The Phalanx has also been criticized for using a much lighter round than its Dutch rival, Goalkeeper. The counter argument to this criticism is that most of the destruction work against incoming missiles is done by the missiles themselves when hit by the round, making any heavier rounds virtually unnecessary. Furthermore, a lighter round allows larger ammunition loads onboard weight-critical ships than guns that use heavier weight round. The optional Enhanced Lethality Cartridge (ELC) now offered in Block 1B updates provides a 50 percent increase in penetrator mass over the earlier ammunition types used.

Also in the latest Block 1B version, the original gun barrels have been replaced by new optimized gun barrels which are 18 inches longer than the original and are substantially thicker. They also feature both a barrel brace and muzzle restraint. All above changes have been made to counter the operational experiences which had reported excessive wear (limited life expectancy) and projectile dispersion patterns.

Block 1 Phalanx Mount

Source: Forecast International

Block 2 Phalanx Mount

Source: Forecast International

Variants/Upgrades

Block 0. The original version of Phalanx. Many of these mounts are being continuously upgraded to Block 1 standard. This original design reportedly suffered from sea corrosion, and special protective casings had to be built around the mount for better durability.

Block 1 Baseline 0 (authorized for limited production in 1986) provided 50 percent more on-mount ammunition capacity for the weapon system. This version was also designed to engage diving targets at steeper angles of attack. The two-dimensional scanning antenna of Block 0 was replaced by a four-plate back-to-back phased-array antenna that continuously searches up through the zenith. Furthermore, a positive cease-fire function matches burst length to target characteristics to conserve ammunition so that more targets can be engaged before reloading. Ammunition load is 50 percent higher than before, available on-mount. This version began the trend toward expanding the system's capability to counter faster, lower altitude maneuvering targets with reduced radar cross-sections.

Block 1 was operationally tested at China Lake from December 3, 1981, to May 21, 1982. Deliveries were started in January 1988. Updating to this standard became a major undertaking, lasting in the US until at least the end of FY97.

In 1983 a modified Phalanx, carrying a four-barrel 30 mm GAU-13 gun, was proposed for the UK Royal Navy. The Signaal Goalkeeper was chosen instead, but the proposal shows to what extent the existing Phalanx could be upgunned with minimum modification. In 1988 it was reported that General Dynamics was also considering two upgunned versions of Phalanx, one with a four-barrel 20 mm gun and one with twin 25 mm guns.

Block 1 Baseline 1 added a pneumatic gun drive, boosting the gun's firing speed to 4,500 rpm, and increased search sensitivity for the radar. It was approved for limited production as part of the FY88 and FY89 production lots and was approved for full production in FY90.

Block 1 Baseline 2. In Baseline 2 version, an internal databus was introduced so that the radar could perform self-testing without the need for an actual approaching aircraft. Plans existed for a time to introduce a Baseline 2A version with a new radar transmitter and a faster reloading system by using a second ammunition drum. It received its Operational Evaluation in FY91 but never went into production.

Block 1 Baseline 3. A Baseline 3 model underwent initial operational test and evaluation in 1991. This was to feature a new Thomson-CSF transmitter, but the system never went into production.

Block 1 Baseline 4. The Baseline 4 version is biased toward surface-target missions. This is expected to include objects such as small attack boats at a short distance. Some modifications to the software are required for that purpose, and the EO sensors (see below) have been found effective in adapting the gun to this new, expanded role. Similar expansion of the role is also seen at Signaal for the Goalkeeper, whose first such mission is on the South Korean Okpo class frigates. New medium-caliber ammunition is being developed for such reconfigured CIWS, featuring dense fields of fragments that simulate the effect achieved by high-velocity bullets fired from a smaller caliber gun.

Block 1A Baseline 2B. This version replaces the original CDC 469A computer with a new one utilizing AMP high-order language (Ada) and a CDI R3000 RISC processor. This was claimed to make the computer 100 times faster than that on the original system. Furthermore, the algorithm is said to take into account targets that are maneuvering (i.e., follow a nonlinear approach track). Essentially, the higher computer processing power is intended to double the gun's effective operating range. Production was launched with a contract issued in FY95.

Block 1B Baseline 2C. This upgrades Phalanx to an anti-surface mode, including also an upgrade in the system's lethality. The system features a Pilkington high-definition IR sensor mounted on the side, being a modified version of the company's HDTI 5-2F thermal imager. This gives the weapon a better capability for tracking and identifying threats against a coastal backdrop. The new radar makes the system better fitted against low-flying targets as encountered in the littoral environment.

The Block 1B upgrade involves integrating a stabilized forward-looking infrared (FLIR) sensor with the existing radar sensor of the system. The result is an enhanced capability to engage, day or night, small high-speed surface craft or low-speed aircraft (helicopters, terrorist aircraft, UAVs), as well as an increase in the range at which maneuvering anti-ship missiles are destroyed.

The new seeker system is incorporated with optimized gun barrels (OGBs) of the system, which are also new. The OGBs are 18 inches longer and significantly thicker than the M61A1 barrels they replace on the cannon. The gun fires 50-round bursts against surface targets, with two-second intervals between the bursts for visual checking. An automatic override is built in to ensure that in case of multiple threats, air targets take priority. Combined with the Block 1B's new muzzle restraint and barrel brace, the OGBs provide Phalanx with an improved dispersion pattern which in turn increases the weapon's engagement ranges.

It was noted that in addition to its successful testing against a variety of real-world threats and littoral warfare threats, the upgraded weapon system also validated its ability to act as an external designation source for the Rolling Airframe Missile (RAM) guided weapon system. This system, which is basically the competitor to Phalanx in the same niche, could therefore conceivably coexist with Phalanx on select platforms, depending on the ships' mission, each system focusing on a different area of close-in defense.

Service entry on platforms other than the testbed was expected to take place before the end of 1999. The Block 1B upgrade presumably went into production in October 1999.

Block 2. The original plans to launch a Block 2 version of the system were canceled in 1992, and instead a path was chosen to offer incremental modifications to the Block 1 design. These resulted in the above-described variations Block 1A, 1B, and their subordinate models.

EO Tracker Add-Ons. Electro-optical sensors are being increasingly looked on as possible ways to boost surveillance and weapon control function effectiveness. In the area of CIWS, both Phalanx and the rival Goalkeeper are actively exploring this technology for their weapon systems, and add-on packages are being offered for retrofit on existing mounts. In August 1990, NSWC circulated a request for information on 3-5µ sensor/trackers suitable to acquire anti-ship missiles at useful ranges. There is also speculation that the US Navy is considering a Phalanx upgrade in which the radar would be moved away from the gun proper, as the radars apparently suffer from gun heat smoke and flash.

Phalanx is now receiving the lightweight Pilkington Optronics High Definition Thermal Imager (HDTI) as a retrofit unit on already-installed systems. The imager scans in the 8-12 µm waveband and has two fields of view.

The contract to Pilkington was awarded in August 1994 and essentially introduces the surface operating mode to the weapon originally designed for defending strictly against anti-air targets (see Baseline 4 above).

Firebox Self-Defense Gun is a concept developed as a possible future alternative for CIWS, featuring multiple composite-made barrels that are preloaded with a rocket-propelled projectile. The projectiles would be guided to their targets by means of a semi-active seeker in the terminal flight phase. The initial launch provided by the platform would be soft, followed by the weapon's own rocket motor accelerating it to a higher speed. For most of the course the weapon would receive guidance from the ship, while toward the end of the run it would employ semi-active guidance.

The Firebox was designed to improve the depth of fire brought to bear on incoming threats, resulting in higher hit-to-kill capability and depth-of-fire capability than on the Phalanx. Firebox was also said to offer improved lethality against advanced threats such as high-speed and maneuverable anti-ship cruise missiles.

The status of this project is not known, but no information has been released about it since 1996, and no funding for it appears to be available in the current naval budget, either. Most likely Firebox has been abandoned in favor of the Block 1B modification kits and the SEA RAM (see respective segments for their descriptions).

Laser Gun Experimentations. Hughes and the Netherlands' Signaal were in a development program whose objective was to replace the 20 mm gun with a high-energy (200 kW) hard-kill laser, based on a Russian technology. Hughes was intended to integrate this laser with the Phalanx and Goalkeeper CIWS mountings. The Hughes derivative of the system was to use on the Phalanx a 200 kW flywheel in place of the magazine and a 500 mm aperture solid-state laser, in lieu of the Gatling gun. The flywheel was expected to have enough power for 100 one-second engagements per repowering (which lasts 10 seconds). Signaal's high-energy laser program differed from that of Hughes; the latter showed keen interest in applying Signaal's engineering capability in its own approach.

This development proceeded very slowly, and no practical application was expected in the near future. No government funding has been awarded to either project in the US defense budgets.

Hughes also has been stated to be developing a low-energy soft-kill system that is to be used in concert with an electronic warfare (EW) system. This development is being conducted in a team with Loral, but its status is unknown. Generally, the interest in laser weapons appears to have waned, and no serious mention of laser weapons has emerged since.

Other Derivatives of CIWS Concept. Martin Marietta at one time proposed a new cased telescoped (CT) 25 mm gun as a possible next-generation Phalanx weapon. Two such guns would fire up to 11,000 rounds per minute, and a mount might accommodate up to 2,600 rounds. The CT round, developed under an Air Force contract, is shorter than a conventional round, and therefore allows for a more compact gun. A 20 mm prototype has fired over 6,000 rounds successfully (and is more reliable than a conventional 20 mm Gatling), and Lockheed Martin stated that the basic CT mechanism would have 67 percent fewer parts than an existing weapon. Estimated reliability is 50,000 rounds between failure, and system life should be 250,000 rounds. Estimated system dispersion is 1.1 mrad, and muzzle velocity should be 3700+ fps. The gun would use a new linear linkless feed system.

Should tests prove successful, the Rockwell dual-band radar under development for TASD was expected to possibly replace the existing Phalanx radar. Its main advantage was that it promised to solve the multipath and glint problems. Due to the extensive acquisitions and mergers in the US defense industry in the last few years, however, it is not known whether this project ever survived under a different corporate entity in a new environment, and there is no information on the current status.

In February 1992, NSWC Dahlgren requested industry proposals for a 60-76 mm gun to be used as a future CIWS, with a total weight of about 10,000 pounds (Phalanx weighs 12,000 pounds). It was to fire long (12- to 15-caliber) rockets at a sustained rate of at least 200 per minute, with a total capacity of 40 to 50 rounds. The rocket's airframe would include a terminal seeker, a midcourse command-link receiver, a control system, a KE penetrator, and a sustainer motor. It would have to be extremely agile and be able to sustain a high acceleration rate on a continuous basis.

<u>Phalanx CIWS1</u>. The UK Royal Navy designation for the weapon system.

<u>PIMS (Phalanx Integrated Maintenance System)</u>. An integrated system that has been developed to decrease maintenance time requirements, increase system availability, and provide the network for future electronic maintenance of the weapon system. Developed under US DoD Standard 2167A software standard, the system includes a ruggedized 486 portable computer that has been designed to interface with the weapon system computer and the below-deck PASS (parameter analysis storage system) computer.

<u>RAM Substitution</u>. The US Navy is in the process of replacing many existing Phalanx mounts with launchers firing the supersonic anti-missile Rolling Airframe Missile (RAM). This is a lightweight, quick-reaction, high-firepower, surface-to-air missile. It is part of the RAM weapon system, composed of a short-range missile and a 10-, 11-, or 21-round launcher, to defend against high-density anti-ship cruise missiles. On the other hand, RAM is seen as filling the gap between the very closest distance self-defense, for which CIWS is still the only solution, and the longer range Standard and Sea Sparrow missile systems. Consequently, the replacement of Phalanxes with RAMs is not a one-to-one ratio operation, but is done on a case-by-case basis, taking carefully into consideration the platform's short-distance defense needs versus existing capabilities. The 21-round launcher is compatible with various platforms ranging from large USN amphibious assault ships to S143 German fast attack craft.

The 5-inch RAM uses the Sidewinder fuze, warhead, and rocket motor, along with the IR seeker from the FIM-92 Stinger. Using a unique rolling airframe concept, the missile maneuvers to its target at supersonic speed.

The rolling airframe approach, using two canard controls, reduces the quantity of guidance and control channels, thereby facilitating packaging, reducing weight, and lowering unit production cost.

RAM was codeveloped and is coproduced by the United States and Germany. Full Scale Engineering Development (FSED) began in 1979. Milestone IIIA Approval for Limited Production (ALP) was granted April 27, 1987, and operational tests were completed in April 1990. Approval for Full Rate Production was granted May 6, 1993. The missile is currently in production at Raytheon Systems Company's plant site in Tucson, Arizona, and also in Germany by a consortium of German companies known as RAMSYS (RAM Systems GmbH).

The RAM weapon system is used by the US and Germany. The US has approved sales of the system to Taiwan for installation on its new PFG-2 guided missile frigates. Denmark has also considered it but will not buy any before 2003, when the replacement of the Willemoes, Niels Juel, and Falster classes begins. Denmark has been a silent partner in the system's development since 1985. Other potential clients include Australia, Italy, Japan, South Korea, Greece, Malaysia, the Netherlands, Spain, Turkey, and the UAE.

SEA RAM. Raytheon Systems Company and RAMSYS GmbH of Germany are developing a system based on the Phalanx CIWS combined with the firepower of the RAM. In this configuration, marketed as SEA RAM, the Gatling gun is replaced with an 11-round launcher for the RIM-116B Block 1 RAM. The system is considered a self-contained unit. It expands the protection envelope of the individual ship out to beyond four kilometers and is capable of dealing with all types of threat typical to littoral operations. The SEA RAM is said to be capable of eight to eleven engagements, while Phalanx is typically good for four to five engagements before it needs to be reloaded.

According to Raytheon, the RAM-based system is better suited for the future supersonic and subsonic threats, including stealthier, faster, and low-flying missiles against which a gun-based system is believed to be less effective. Thanks to the use of the footprint and power requirements of Phalanx, retrofitting existing mounts over to SEA RAM should be relatively effortless.

The SEA RAM system is offered not only as a retrofit to existing Phalanx clients, but also as a stand-alone system for different types of smaller naval craft or fleet replenishment ships. It is also reported to be a potential UK national alternative for the tri-national Project Horizon (CNGF). It was tested on the British destroyer HMS *York* during 2001 and was removed from that ship once those trials were ended.

Program Review

Background. This system was first proposed in 1968 as part of the early anti-ship missile defense program prompted by the sinking of the Israeli destroyer INS *Eilat*. The US Navy (USN) requirement for a close-in weapon system (CIWS) was given greater impetus by the appearance of the Russian Project 670 (Charlie-I) class missile-launching submarines in the late 1960s. The advent of these submarines meant that submerged-launched missiles could be fired at very close range, providing little or no warning. This precluded the use of area defense weapons against such missiles and pointed to an urgent need for a capable CIWS.

Feasibility contracts for the Phalanx system were awarded to General Dynamics in Pomona, California, in 1969, to demonstrate a closed-loop fire control system. The first closed-loop spotting system was demonstrated at White Sands in 1970. The first two prototype systems were delivered in January 1973, and one of these was installed aboard the destroyer USS *King* from August 1973 through March 1974 for at-sea evaluation. During these evaluations, the mount showed a certain lack of target discrimination and, on one notorious occasion, enthusiastically engaged Santa Catalina Island. There were also doubts as to whether Phalanx would be able to destroy incoming cruise missiles.

In July 1974, General Dynamics received a US$10 million contract to produce six more systems for use as operational suitability models. These were used in 1975 lethality tests against missiles. In 1976-77, a Phalanx system was fitted aboard the destroyer USS *Bigelow* to test the weapon's functioning in an electronic jamming environment.

The Phalanx won approval for service use in July 1977, followed by a favorable approval for full production in September 1977. General Dynamics was awarded a US$50 million initial production contract subsequent to the decision. The first-production deliveries were made in 1979, and the first installations completed in 1980 on the aircraft carriers USS *America*, USS *Enterprise*, and USS *Coral Sea*, and the cruisers USS *Biddle* and USS *England*.

In 1982, the UK Royal Navy (UKRN) lost two ships, the destroyer HMS *Sheffield* and the bulk carrier MV *Atlantic Conveyor*, to Exocet missile attacks during the Falklands War. These losses highlighted the absence of any point defenses on board non-Seawolf equipped ships and also forced the UKRN to deploy the two Seawolf-armed Type 22 frigates as close-in escorts for the air-capable ships HMS *Hermes* and HMS *Invincible*. As a result, the UKRN ordered a total of 32 Phalanx Mk 15 guns (the order valued at US$275 million) to equip a number of frigates, destroyers, and air-capable ships.

During the early 1980s, the USN became concerned that the Phalanx might have difficulty in handling the threats expected to occur in the 1990s from low-flying and high-flying cruise missiles. A Block 1 Upgrade program was begun in PE#64358N Close-In Weapon System (Phalanx). During 1985, the Navy completed firing tests aboard the frigate USS *Tisdale* of a Block 1 Production Support Model in clear electronic countermeasures environments. The service also completed development of a dual firing capability and held advanced 20-, 25-, and 30-millimeter penetrator tests against inert and live targets simulating low-level threats. This was part of the Phalanx Advance Concept Effectiveness Studies program.

Block 1 Baseline 0 was approved for limited production in FY85. It provides increased performance in search-elevation coverage, increased velocity coverage, a larger magazine, augmented reliability, BITE, and better system-operability test (SOT) and fault-isolation test (FIT) programs. Deliveries began in January 1988 and the weapons entered service in October 1988. The first four were installed on board the battleship USS *Wisconsin*. A new upgrade (a pneumatic gun drive) increased rate of fire from 3,000 to 4,500 rds/min, and further improvements are being investigated.

During this period, the USN incorporated Commander, Operational Test and Evaluation Force developmental and operational testing recommendations into a design model. The USN also held electromagnetic interference testing between the Phalanx and an SLQ-32 at the Naval Surface Weapons Center. Evaluations of the development options for the evolution of Block 1 and concept studies for a revolutionary close-in weapon system to meet the threat in the year 2000 were also conducted.

In 1987-88, the follow-on system was formally designated CIWS-2000. In January 1988, a congressional conference committee refused further funding for CIWS-2000 until the USN had evaluated Goalkeeper. Admiral Metcalf, the outgoing chief of surface warfare, had already tried to cancel CIWS-2000 in the fall of 1987, arguing that the system represented an insufficient advance over the existing Phalanx, and that more revolutionary, rather than evolutionary, counters to attacking missiles were needed.

At the 1989 US Navy League Exhibition, GE displayed a new Phalanx Magazine Loading System, by means of which two gunners can reload a mount in less than five minutes, compared with 30 minutes at present. It uses a second ammunition drum, mounted on top of the electronics enclosure, that feeds rounds into the main drum when it is empty.

In October 1990, General Electric awarded a contract to Thomson-CSF to develop a new radar for the system. In late 1990, General Electric informed the USN that it would be unable to deliver the radar at the agreed price of US$500,000. Due to the price increase, the radar contract was canceled. The service also qualified the 20 mm tungsten penetrator round for Phalanx service.

Plans for a follow-on Block 2 were shelved in 1991 in favor of continued incremental improvements to Block 1. The GE contract for a Phalanx radar upgrade was canceled in December 1991. Phalanx was experimentally integrated with a FLIR at Dahlgren in spring 1991. CIWS Block 1 Baseline 4, which entered service in FY97, includes a major sensor upgrade (to better detect small targets in high clutter, and for better ECCM) and a high-order language (HOL) computer upgrade to increase capability against maneuvering targets.

The UKRN ordered two additional systems in September 1994 for fleet auxiliaries. The Pakistani Navy purchased six Type 21 frigates from the UK and replaced the Seacat installations on two of these with Phalanx Mk 15 systems held in store.

Also in 1994, a test-firing of a Phalanx Mk 15 in Taiwan dramatically failed when the gun, set to automatic engagement for a firing trial against a target towed by a Learjet, engaged the wrong target and shot down the towplane. The key to the tragedy is said to have been the lack of an optronic subsystem on the Taiwanese guns, which would have ensured that the fire control radars had locked onto the correct target.

Throughout the last five years of the 20th century, the Phalanx Mk 15 continued to be exported to a number of countries and be installed on new-construction US warships, most notably those of the DDG-51 Arleigh Burke class. The Japanese Navy continued to purchase the systems for installation on the Murasame class destroyers. However, the impetus was already beginning to fade from the program as missile-based close-in weapon systems gained in prominence. By mid-1998, such systems, most notably the RIM-116 Rolling Airframe Missile (RAM), were taking up much of the design attention previously occupied by Phalanx and its equivalents.

Symptomatic of Phalanx's decline as a primary point defense system was the 1998 development of the Surface Mode Upgrade, a high-definition thermal imager that increased the ability of the mount to engage surface targets such as small craft and also increased its effectiveness against sea-skimming missiles. A surface mode had been suggested for Phalanx for some years, but the weapon had always been regarded as too valuable in its point defense role to consider other applications. With that point role being taken over by other systems, the time was ripe for the Surface Mode Upgrade.

Developmental test certification shot of the upgrade was performed in April 1997, followed by developmental testing aboard the USN Self-Defense Ship (SDTS, formerly known as the USS *Decatur*) immediately thereafter. The air-defense developmental testing was scheduled to be completed by the end of May, and production of kits for upgrading existing guns to Block 1B standard was also to begin in 1997. However, as of spring 1997, no funds had been allocated for 1B production in the FY98 Navy budget.

The technical evaluation (TECHEVAL) of Block 1B was completed in early February 1999, and the Operational Evaluation (OPEVAL) was supposed to last from April 19 to 23. After that, the ship on board which the weapon was installed (guided missile frigate FFG 36 *Underwood*) for the tests was scheduled to become the first platform to deploy the fully operational Block 1B system. Due to external circumstances, however, the tests were delayed and were not completed until September. The deployment on board USS *Underwood* then took place in mid-October.

Simultaneously with this development came news of the new SEA RAM system. This is a combination of the Phalanx mounting and fire control system with the 11-round RIM-116 RAM launcher to give a new and potentially very effective terminal defense system. In late 2000 it was announced that a prototype of this system would be installed on the British destroyer HMS *York* for extended operational trials. While all parties stress that this trial arrangement does not have any greater significance than the use of a convenient platform for sea trials, it does highlight the potential for SEA RAM as a replacement for Phalanx. These trials continued throughout 2001 and were reported to have been successful. HMS *York* has now been converted back to standard Type 42 Batch III configuration.

Funding

The USN received US$120.3 million in FY84 and US$163 million in FY85 for Phalanx procurement. Further development efforts continued through 1987. These efforts focused both on software improvements to keep up with threat developments and on means to protect the system from destroyed anti-ship missiles. The USN received US$127.5 million in FY86 for 38 Phalanx systems. Phalanx installation continued on all new-construction guided missile frigates, destroyers, and guided missile cruisers, as well as retrofitting to all cruisers, Spruance class destroyers, all amphibious warships, and most auxiliaries.

For FY87, the USN asked for US$105.6 million for 27 Mk 15 Phalanx systems, receiving US$102.2 million for 24 systems. During FY87, most of the Phalanx systems that were procured were used for retrofitting to amphibious and auxiliary ships. This order brought the Navy’s total Phalanx procurement at the time to 379 systems. The USN had opened the Phalanx program to competition in early 1987 with a Request for Proposals for second sourcing. On February 18, 1987, the USN awarded General Electric’s Armament Systems Division a US$12.4 million contract for second-source qualification and pilot production of the Mk 15 Phalanx. Research and development efforts in FY87 included the commencement of developmental testing of the Block 1 Upgrade against tactical missiles, and the continuing evaluation of lethality improvements and options for a follow-on terminal defense system.

The National Defense Authorization Act for FY98 authorized $15 million for Phalanx surface mode (PSuM) Block 1B upgrade kits. Research, Development, Test and Evaluation (RDT&E) funding was allocated to Phalanx in FY97 ($4.7 million) but none thereafter. The Rolling Airframe Missile (RAM), in contrast, continues to enjoy RDT&E funding.

Recent funding of Phalanx has been for the ammunition and conversion work. The US defense budget for FY99 included line item numbers 433 and 4336 under the Navy and Marine Corps Procurement of Ammunition section. Only $2.8 million was requested for FY99. It is not known whether this line item was intended to include the conversion of existing mounts to accept the RAM Block 1 missile, but in the future most funding activity will be for replacements and not for new procurement of any more entire Phalanx systems. Depending on the platform, however, some Phalanxes will be maintained and upgraded even while RAMs are being brought in.

RAM guided missile launching system (GMLS) installations are performed during overhauls or regular shipyard availability. RAM will be installed on LHA, LSD, LHD, DD-963, CVN, and LPD ship classes of the US Navy. The US defense budget’s procurement plan (P-1) includes a line item for the installation/conversion work under Other Procurement, Navy/4 Ordnance Support Equipment, with title 5238: Rolling Airframe Missile. The appropriated funds for Fiscal Year 1999 amounted to $61.2 million, peaking in FY98 at $68.3 million. The amounts projected for the subsequent years are as follows: FY00 – $27.9 million; FY01 – $10.3 million; FY02 – $44 million; FY03 – $45.3 million.

Recent Contracts

Contractor	Award ($ millions)	Date/Description
US DoD	84.1	September 1995 – Procurement of 23 weapon systems to be delivered by July 1998 to Japan, Australia, Taiwan, and the UK and US navies.
Hughes Missile Systems	46	May 1996 – Greece requests the purchase of four Phalanx systems, with test ammunition, spare parts, and other elements of program support.
US Navy	23.1	July 1996 – Privatization of the life-cycle maintenance support. Cumulative value, if options are exercised, will be US$149.9 million. Work completion was projected for September 2001.
US DoD	N/A	July 1996 – 20,000 rounds of Phalanx ammunition to Thailand, to be used on a Knox class frigate; 4,000 rounds to Egypt, on a Perry class frigate (third in a series).
Hughes Missile Systems	9.8	March 1997 – FMS modification contract for engineering support, encompassing purchases for the USN, Japan, UK, Taiwan, Australia.
Hughes Missile Systems	2.28	November 1997 – Modification contract for life-cycle maintenance support (partial cumulative value $17.8 million); also involves RAM.
Devenport Management Ltd (DML)	8.2	December 1997 – UK MoD contract for the overhauling and upgrading of 13 Phalanx weapon systems over the next four years.
Raytheon Systems Co (formerly Hughes Missile Systems)	5.97	March 1998 – Modification to earlier contract number N00024-98-C-5406: design agent services for the USN and FMS customers (Japan, UK, Taiwan, Greece, Australia, unspecified others).
Raytheon Systems Co	17.4	April 1998 – Engineering support for RAM Mk 31.
Itochu Aviation Inc	49	May 11, 1998 – First direct sale to Japan, concerning four Block 1A systems for two Murasame destroyers.
Raytheon Systems Co	22.4	July 9, 1998 – Production contract for Block 1B Surface Mode mod kits.
Signal Technology Corp	(13.5)	October 1998 – A two-year contract for electronic components for Phalanx as well as AMRAAM, Standard Missile, and Patriot programs.
Paravant Computer Systems	N/A	Late 1998 – Sole-source contract for the configuration of laptop computers for Phalanx portable maintenance units (PMUs) (COTS parts).
Hughes Missile Systems	10.3	January 4, 1999 – Partial exercise of options on a previous contract for life-cycle maintenance support. Expected completion by September 1999.
Raytheon Systems Co	5	April 29, 1999 – Engineering and technical design services (modifications) for US Navy (72%) plus assorted foreign clients (28%).
Raytheon Systems Co	10	April 30, 1999 – Overhaul, repair, and upgrade of eight systems in Canada.
Raytheon Systems Co	7	October 1999 – Contract for three ordnance alteration systems. (Block 1Bs?), with completion projected for June 2001.

Timetable

Month	Year	Major Development
Nov	1970	Advanced Phalanx development begins
Aug	1973	At-sea operational testing of first prototype launched
Jun	1974	Lethality testing against cruise missiles begins
Oct	1975	First dynamic lethality test completed
Feb	1976	Second dynamic lethality test completed
Jun	1977	Operational evaluation completed
Sep	1977	Production contract awarded to General Dynamics
	1984	Block 1 Upgrade program begins
Mar	1984	Operational testing of first prototype completed
	1987	Block 1 operational evaluation conducted
Apr	1987	General Electric selected as second-source supplier
	1988	Approval given for full production of Block 1 upgrades
	1991	Block 2 Upgrade canceled
Aug	1994	Phalanx Surface Mode (PSuM) upgrade with new sensor begins
Mar	1996	Pilkington Optronics begins thermal imager deliveries to UKRN
Sep	1996	Support center for Phalanx CIWS opens in Calgary, Canada
Early	1997	PSuM (Block 1B) upgrade deliveries completed in the UK
Sep	1997	Devenport's first overhaul contract on 10 UKRN systems completed
	1997	PSuM deliveries to US Navy begin
May	1998	First direct sale to Japan
Jun	1998	Fleet firing phase of RAM Block 1 completed
Jul	1998	Production contract for Phalanx Block 1B kits issued (deferred?)
Nov	1998	SEA RAM introduced
Dec	1998	RAM Block 1 developmental test shots fired
Feb	1999	Phalanx Block 1B technical evaluation completed
Apr	1999	Operational evaluation of Block 1B begins
Sep	1999	OPEVAL completed
Oct	1999	USS *Underwood* first platform to deploy new version in service
Oct	1999	Production of Block 1B begins

Worldwide Distribution

Australia	8 Block 1	**Pakistan**	6 Block 0
Bahrain	1 Block 1	**Poland**	2 Block 0
Brazil	1 Block 0	**Portugal**	3 Block 1
Canada	8 Block 0, 12 Block 1	**Saudi Arabia**	13 Block 0
Egypt	2 Block 0, 4 Block 1	**Spain**	1 Block 0
Greece	4 Block 2, 6 Block 1, 6 Block 0	**Taiwan**	29 Block 1
Israel	13 Block 0	**Thailand**	2 Block 1
Japan	98 Block 1	**Turkey**	15 Block 1
Malaysia	1 Block 0	**United Kingdom**	32 Block 1
Morocco	1 Block 0	**United States**	358 Total for all variants
New Zealand	3 Block 1		

Forecast Rationale

Of the 900 Phalanx mounts reported to have been procured by the US Navy and by export customers, approximately 630 are identified as being installed on ships currently in service. This leaves a balance of 270 systems, a number that includes those weapons kept in a replacement pool to re-equip ships whose mounts are removed for repairs, overhaul, and upgrading. Even if a generous allowance is made for that replacement pool, there are still many more mounts available than likely platforms for them to equip. In fact, the supply of pre-owned but certified and upgraded Phalanx mounts is more than adequate to fill demand well beyond the next decade. Once the older Phalanxes come up for modernization they are either upgraded to Block 1 A/B standard or replaced altogether with RAMs (or now more likely with SEA RAMs). The different upgrade and modification packages issued for Phalanx throughout its lifetime have been used to enhance the system's firepower and tracking capabilities. The 1B modification, which includes a high-definition thermal imager for more accurate target tracking, represents the last major investment for the system.

This situation does not alter the fact that the Mk 15 Phalanx CIWS is by far the dominant CIWS in service around the world. It also continues to be the backbone of the US Navy close-in anti-missile defenses, and one or two such mounts are fitted on every significant US surface combatant. As a result of these very large US orders, Phalanx has been able to command a relatively low purchase price. It also has a low installation impact on the design of the ship, which has made Phalanx a natural choice for a retrofit weapon system on existing combatants. In an ironic turn of events, Phalanx's very suitability for its market has now resulted in the large excess of mounts over platforms, since the forces draw-down of the 1990s retired many Phalanx platforms.

The upgrade to surface mode is a major enhancement that will ensure Phalanx will be around for many years to come. We do not foresee any additional production at this time due to the easy availability of upgraded pre-owned units. Instead, emphasis in the Phalanx program will be placed on upgrade kits and retrofits of existing mounts with enhanced hardware and/or computer systems. Nevertheless, if evidence of new production of entire systems is obtained, this forecast will be modified accordingly.

Ten-Year Outlook

No new production of this series is projected. Only modernization and upgrade activity of the onboard systems will continue throughout the forecast period; the forecast chart is therefore omitted.

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