APG-73(V) - Archived 10/2008

Outlook

- With the delivery of the last APG-73 in June 2006, Raytheon's focus has shifted from production to maintenance, a market that could become very lucrative
- The AESA upgrade to the APG-73 is designated the APG-79(V); it will most likely replace the APG-73 in the marketplace
- No new sales of the APG-73 are expected, despite a continuous stream of maintenance and upgrade contracts
- The radar is widely used on the international market, and future upgrades are possible
- This report will be archived in 2008

Orientation

Description. Airborne, multimode, pulse-Doppler fire-control radar. The APG-73 is an upgrade to the APG-65.

Sponsor
U.S. Navy
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Status. Ongoing logistics support. Upgrade program approved.

Total Produced. According to Raytheon, between 1993 and 2006, when production ceased, 932 APG-73 radars were delivered to the U.S. Navy and to Australia, Canada, Finland, Malaysia, and Switzerland.

Application. F/A-18C/D and E/F; EA-18G; F-18D.

Price Range. When production ended in 2006, the radar's estimated average unit cost was $2.5 million. The AESA retrofit onto the APG-73 is estimated to cost from $2.5 to $3.0 million per aircraft.

Contractors

Prime

Raytheon Space & Airborne Systems	http://www.raytheon.com/businesses/rsas, 2000 E El Segundo Blvd, El Segundo, CA 90245 United States, Tel: + 1 (310) 647-1000, Fax: + 1 (310) 647-0734, Email: SAS_Comms_PA@raytheon.com, Prime

APG-73(V)

Technical Data

	Metric	U.S.
Dimensions		
Weight (excluding rack)	154 kg	340 lb
Total weight	227 kg	500 lb
Volume (excluding antenna)	0.126 m^3	4.5 ft^3
Antenna (approximate diameter)	71 cm	28 in
Characteristics		
Frequency	8 to 12 GHz	
PRF	Low Medium High	
Range	>60 nm	
PSP	60 MCOPS	
A/D converter	5 MHz (air-to-air) 58 MHz (air-to-ground)	
Memory		
Signal processor	1M word	
Data processor	2M word	
Antenna	Low sidelobe planar array	
Drive	Direct electric APG-79(V) will incorporate active-array antenna	
LRUs	Antenna Transmitter Power supply Radar receiver Radar data processor	
Operating modes		
Air-to-air modes	Velocity search (high PRF) Range-while-search (high/medium PRF) Track-while-scan (maintains 10, displays 8) Short-range automatic acquisition Gun acquisition Vertical scan acquisition Boresight acquisition Wide-angle acquisition Single target track Gun director	
Air-to-surface modes	Real beam ground map Radar navigation ground map Doppler beam sharpened sector Doppler beam sharpened patch Medium-resolution synthetic aperture radar Fixed target track Ground moving target indication/track Sea surface search Air-to-surface ranging Terrain avoidance Precision velocity update Inverse range angle	
Air-to-air fighter capability	All-aspect target detection Clean scope in look-up and look-down Long-range search and track Automatic acquisition Multiple target track	

Characteristics

Air-to-surface attack capability	High-resolution ground mapping for navigation, weapons delivery, and sensor cueing Compatible with weapons in the U.S. and NATO inventories
MTBF	100 hr

Design Features. The APG-73(V) is an all-digital, multimode radar for use in both air-to-air and air-to-ground combat missions. It is an all weather, coherent, multimode, multi-waveform search-and-track sensor based primarily on the APG-65(V) design, with technology crossovers from the APG-70(V) and APG-71(V) radars. The APG-73(V) uses the same antenna and traveling wave tube (TWT) transmitter as the APG-65(V), but has a new radar data processor, power supply, and receiver/exciter, as well as increased memory, bandwidth, and frequency agility. Analog/digital sampling rates are higher. In addition, the radar features better resolution, a new navigation/ground map mode, and improved electronic counter-counter-measures (ECCM), as well as some modes from the APG-70(V) radar.

A single radar data processor replaced the signal processor and data processor units in the older radar, and incorporated technologies to provide higher throughputs and greater memory capacity than found on the original APG-65(V).

The new power supply is solid-state for better power conversion, and shows a significant increase in reliability. Power supply failure has been an ongoing problem with airborne radars. During tests of the new system, one of the units ran 2,500 hours with only one failure. A snap-in rack design provides plug-in modules with power, cooling, and electronic connections, and features quick-change replacement.

Using multichip modules containing multiple gate arrays, the signal processor throughput has been increased from 7.2 MOPS to 60 MOPS. A general-purpose 1750A computer provides mode control, antenna control, target tracking, and display processing, and operates at more than 2 million instructions per second. The computer has a 2M-word firm memory and a 256K 16-bit working memory.

The radar receiver, featuring extensive MMIC (Monolithic Microwave Integrated Circuit) technology, was designed to support growth requirements well into the 21st century through the addition of new circuit boards. It has the input/output capacity to support a next-generation active-array antenna.

The programmable signal processor allows the radar to adapt quickly to new weapons or tactics via software changes, negating the need to make changes to any of the embedded source codes or hardware modifications. The radar incorporates automated anti-jam features, the result of development of advanced digital and analog technology. Field upgrades of ECCM techniques can be accomplished by reprogramming the signal and data processors' software, quickly adapting the system to new threats.

The design ensures growth because only 60 percent of the hardware capacity is used by the original software; 40 percent of the system's speed and memory remains available for enhancement. The original APG-73(V) was designed to accommodate an electronically scanned array. The processing capacity, wiring harnesses, and RF connections needed for the active antenna were built into the hardware.

The fast analog-to-digital air-to-air converter (11-bit, 5 MHz) produces a radar resolution cell of approximately 100 feet. The 6-bit, 58-MHz analog-to-digital air-to-ground converter improves radar mapping resolution significantly, thus improving air-to-ground targeting.

The faster signal processor offers better Doppler resolution than the APG-65(V). Fast Fourier transforms can be used more effectively, improving discrimination of closely spaced targets and ECCM performance. The system uses a Mil-Std-1750A processing architecture. An additional 20 MCOPS can be added via a vacant card slot. To improve reliability, the signal processors are combined into one unit and interconnected by a backplane instead of wire harnesses.

Wider bandwidth makes it possible for the radar to operate with Marine Corps targeting beacons. This bandwidth also helps the radar to tune away from jamming signals. Increased binary pulse compression improves air-to-air and air-to-ground range resolution and focuses more power on the target. The APG-73(V) uses a filter to improve radar performance in clutter conditions. By combining components from proven equipment, the system capitalizes on known designs and components.

Built-in test equipment can isolate problems to an individual module, which can be changed quickly without removing the rack. Hardware can be upgraded by replacing modules.

APG-73(V)

Operational Characteristics

Search and Track Modes

- Velocity Search – Provides maximum detection range against head-on aspect targets (high PRF)
- Range While Search – Detects all-aspect targets (high/medium PRF)
- Track While Scan – Provides the AMRAAM with fire-and-forget capability when integrated with the F/A-18 (maintains 10, displays 8)
- Single Target Track – Tracks a single high-priority target
- Rapid Assessment – Expands the region centered on a singly tracked target; separates closely spaced targets

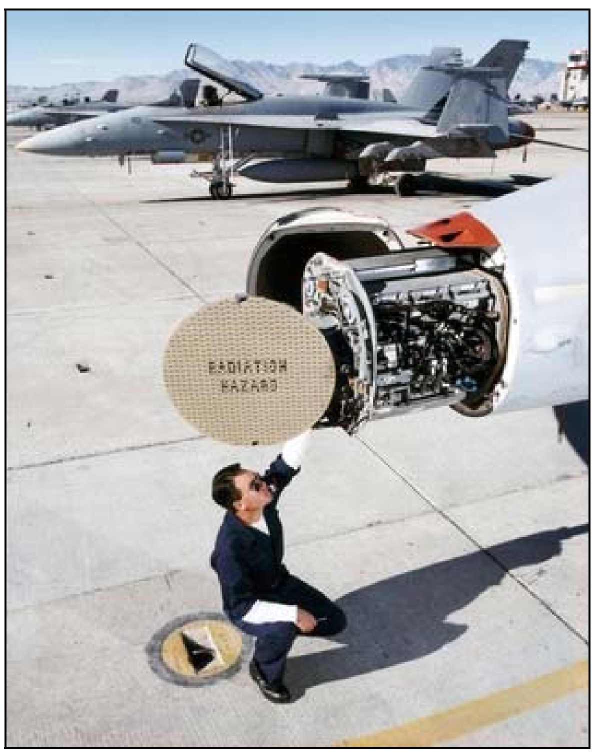
Air Combat Maneuvering Modes

- Head-Up Display – Scans the entire area covered by the head-up display and automatically locks onto the first target within a pre-selected range
- Vertical Acquisition – Vertically scans a narrow width and locks onto the first target within a pre-selected range
- Boresight Acquisition – Enables the pilot to point the aircraft at a desired target that the radar acquires automatically; several targets can be acquired and passed on until the desired target is acquired

For surface attack missions, the radar offers a high-resolution surface mapping feature that can be used with land- or sea-search modes. A Terrain Avoidance mode is used for low- level penetration missions, and an Air-to-Surface Ranging mode is available for the accurate delivery of both guided and unguided munitions. A specialized Sea Search mode will enable the system to acquire and track ship targets in any sea state.

Designers claim that the enhanced system can produce ground radar maps comparable to those found on the F-15E and U-2. Advanced image correlation algorithms make precision strike missions possible.

The APG-73(V) reduces pilot workload during all phases of both air-to-air and air-to-surface missions. During air-to-air missions, it provides total visibility against airborne targets in all aspects, at any altitude, and through all target maneuvers. Like the APG-65(V) radar, the system accommodates the F/A-18's hands-on-throttle-and-stick (HOTAS) operation.



APG-73(V)

Source: Raytheon

Variants/Upgrades

Radar Upgrade Phase I. The upgrade from the basic APG-65(V) to the APG-73(V), with full-rate production of Phase I approved in October 1996. Phase I increased the radar processing speed and memory and improved receiver sensitivity, increasing air-to-air detection range and improving ECCM capabilities.

Radar Upgrade Phase II. This upgrade added a high-resolution search-and-rescue (SAR) mode. The upgrade added a small inertial navigation sensor (to measure aircraft movement at the radar itself), a stretch generator module, and a special test equipment instrumentation and reconnaissance module. (Aircraft flexing causes errors in measurements made using the aircraft inertial system that negate the precise measurements needed for SAR operations.)

Phase II provided high-resolution ground mapping for reconnaissance capability and autonomous targeting for the Joint Stand-Off Weapon System (JSOW) and Joint Direct Attack Munition (JDAM). It was introduced in the USMC F/A-18D RC reconnaissance aircraft in 1997, and became standard in 1999.

Radar Upgrade Phase III. This upgraded system had an active, electronically scanned array antenna (AESA) that greatly improved ECCM performance and near simultaneous multimission capability, and enhanced signature characteristics.

APG-79(V) AESA Radar. In November 1999, Boeing selected Raytheon to provide the active electronically scanned array (AESA) antenna for the F/A-18E/F. This was a revolutionary leap in capability. It has at least 10 times more capability than the APG-73(V), and offers much better performance than previous radar upgrades and developments.

Program Review

The APG-65(V) that equipped the F/A-18A/B was upgraded continually since entering service with the F/A-18 in the late 1970s, but reached its memory and processing limits by the late 1980s. New technologies were introduced in other (then) Hughes radars, especially the APG-70(V) carried by the F-15E. Upgrade efforts began in 1988.

APG-73 Result of Advances in APG-65 Capability

Operation Desert Storm showed that the F/A-18 would benefit greatly from an improved all-weather capability. A "strip map" mode and the ability to interface with the advanced tactical airborne reconnaissance system datalink would be major improvements. The APG-73(V) was the result of this need. It was based on technology developed with the APG-65 as well as other radars.

A production contract was signed in 1991 for 12 production units. In April 1992, the first flight test demonstrated both long-range detection and ground mapping. The first production radar was delivered to McDonnell Douglas Aerospace on July 30, 1993.

In July 1994, the Naval Air Systems Command announced that it would issue a cost/reimbursement-type contract for research and development associated with Phase II of the APG-73(V) radar upgrade program.

The first U.S. radars began arriving in the Fleet in late 1994, with the first Finnish radar following in February 1995 and the first Swiss radar arriving in July 1995. Malaysia received its first radar in May 1996. In early 1997, Australia decided to acquire two systems to evaluate as a possible upgrade for its F/A-18C/Ds. The Royal Australian Air Force did not begin full-scale upgrades until 2000. In total, 71 aircraft were upgraded with the APG-73 over three years, with 20 percent of the work taking place in Australia.

In November 1995, the U.S. Air Force awarded a $500,000 contract for a one-year first phase of a technology program to develop a low-cost airborne active-array radar. Under the effort, 350 transmit/receive modules were to be produced.

At the conclusion of the first phase, the USAF initiated production of a 7-square-foot prototype antenna. Designers capitalized on work under way for the F-22 radar, the APG-77(V).

Joint U.S.-Canada Project

In July 1995, the U.S. announced a joint U.S.-Canada project to develop high- and very-high-resolution data in the radar's strip map and spotlight modes. This effort would support an increased reconnaissance capability and more accurate delivery of standard and special weapons.

APG-73(V)

As a prelude to an upgrade program for the Marine Corps' F/A-18Ds, a U.S. Marine F/A-18D demonstrated the missile launch and homing capabilities of the APG-73(V) in live-fire exercises. Using the radar, units successfully launched AIM-7 Sparrow, AIM-9 Sidewinder, AGM-88 HARM, and AIM-120 AMRAAM missiles. In early 1999, the U.S. Marine Corps launched an upgrade program (ECP-583) for its fleet of F/A-18C/Ds. The upgraded avionics suite included the APG-73(V).

In November 1999, Boeing selected Raytheon to provide a state-of-the-art AESA radar for the F/A-18E/F Super Hornet under an agreement between Boeing and the U.S. Navy. Originally, the U.S. Navy dubbed this upgrade the APG-73 RUG III, but it later received the official nomenclature of APG-79(V). A Navy engineering and manufacturing development (EMD) contract was expected in early 2001. Deliveries began in 2004.

Boeing delivered the first full-rate-production F/A-18F to the Navy in October 2001.

U.S. Navy Procures Radar Upgrade Kits

The Naval Air Systems Command then announced a requirement for approximately seven Phase II APG-73(V) radar upgrade kits, with an option for at least six additional kits. Then, in a July 2002 edition of *Federal Business Opportunities*, the U.S. Naval Air Systems Command announced a requirement for approximately six APG-73(V) radar upgrade kits, with an option for one additional kit. In a January 2003 edition of *Federal Business Opportunities*, the Naval Air Systems Command announced an intent to negotiate with Raytheon for APG-73(V) radar upgrade Phase I retrofit kits and APG-73(V) transmitter upgrade kits, with an option for a non-recurring engineering (NRE) effort related to obsolete parts necessary for modification of the F/A-18 aircraft. The overall effort would involve a base delivery order with three options.

The base order would be for up to five radar retrofit kits and up to five transmitter upgrade kits, as well as an option for the NRE effort for FY03. The first option would allow for the purchase of six APG-73(V) radar upgrade Phase I retrofit kits, six transmitter upgrade kits, and an option for NRE for FY04. The second option would allow for the purchase of four radar upgrade kits, four transmitter kits, and an option for NRE for FY05. The third option would allow for the purchase of 10 radar upgrade kits, 10 transmitter kits, and an option for NRE for FY06.

This effort did not preclude orders for additional radar upgrade kits and transmitter kits, an expanded NRE effort, or accelerated procurement, all of which could result from a congressional plus-up or Foreign Military Sales (FMS) requirements.

In October 2004, the U.S. Air Force contracted to modernize the B-2 radar with AESA technology derived from the APG-73 family of radars. Project completion target date is FY11.

Last APG-73 Delivered in June 2006

Raytheon's final production APG-73 radar has been delivered to the U.S. Navy to be installed on an F/A-18E/F. Meanwhile, Raytheon has been awarded a $22.8 million contract to provide spares and support. This contract could eventually be worth $40 million. With these contracts, Raytheon has shifted the focus of its APG-65 and APG-73 radar programs from production to maintenance, a change Raytheon believes will be quite profitable.

Already, Raytheon has been awarded two contracts to maintain existing APG-73s. In early 2007, the U.S. Naval Inventory Control Point awarded the company a contract worth $9.8 million for the provision of components used in repairs. The second contract is a nine-year in-service support (ISS) agreement awarded by the government of Australia.

Contracts/Orders & Options

(Contracts over $5 million.)

Contractor	Award ($ millions)	Date/Description
Raytheon	10.2	Sep 2003 – Delivery order against a previously issued basic ordering agreement for the procurement and installation of ECP-583 kits to upgrade the APG-65(V) radar to the next-generation APG-73(V) for the F/A-18E/F. In addition, this contract provided for the procurement of two micro switch parts for assembly of the APG-73(V). Completed Aug 2005. (N00383-01-G-1000A)
Raytheon	9.7	Feb 2004 – FFP contract for purchase of APG-73(V) receiver spares for the F/A-18E/F. Completed December 2005. (N00383-04-G-001H-5009)

Contractor	Award ($ millions)	Date/Description
Raytheon	11.5	Apr 2004 – Delivery order under a previously issued basic ordering agreement for the procurement of five APG-73(V) radar upgrade Phase I retrofit kits for the F/A-18 modernization program. Completed Mar 2006. (N00383-01-G-100A)
Raytheon	5.9	Sep 2004 – FFP delivery order against a previously awarded basic ordering agreement for 18 APG-73 antennas for F/A-18 aircraft. Completed Jun 2007. (N00383-04-G-001H)
Raytheon	12.6	Dec 2004 – Delivery order against a previously awarded basic ordering agreement for procurement of APG-73 receivers (spares) for the F/A-18E/F. Completed Dec 2006. (N00383-04-G-001H, 5032)
Raytheon	22.9	Mar 2006 – FFP order against a previously awarded basic ordering agreement for APG-73 spares used on the F/A-18. Completed Sep 2007. (N00383-04-G-001H)
Raytheon	9.8	Jan 2007 – Ceiling-priced delivery order under a previously awarded basic ordering agreement for repair of APG-73 components. Completed Sep 2007.

Timetable

Month	Year	Major Development
	1989	Radar upgrade program approved
Mar	1992	First flight test on an F/A-18
Sep	1992	Program review, long-lead parts for full-rate production approved
Jul	1993	First delivery, initial production
May	1994	First two F/A-18s with APG-73(V) become operational
Jul	1994	F/A-18E/F Design Review
Feb	1995	First international delivery, to Finland
Jul	1995	First radar delivery to Switzerland
May	1996	First radar delivery to Malaysia
Oct	1996	Full-rate production of APG-73(V) radar upgrade Phase I approved
May	1997	F/A-18E/F procurement plans changed
Nov	1999	Raytheon selected to provide AESA for F/A-18E/F
Jan	2000	Australian production (71 aircraft) contract awarded
Feb	2001	AESA Milestone II
Oct	2001	First full-rate-production F/A-18E/F delivered
Dec	2001	RAAF deliveries begin
Oct	2002	Production by Australia ends
	2003	RAAF deliveries completed
Jun	2006	Last APG-73 delivered

Worldwide Distribution/Inventories

The **U.S. Navy** and **USMC** are installing the radar on F/A-18C/D aircraft, and will install it on the F/A-18E/F.

Australia retrofitted the APG-73(V) into its F/A-18A/B fleet of 71 aircraft.
Canada upgraded its fleet of CF-18s with new avionics, including the APF-73(V).
Finland uses the radar on 64 F-18Ds.
Malaysia acquired the radar for its 48 F/A-18s.
Switzerland uses the APG-73(V) on its 34 F/A-18C/Ds, and could install it in another 8 to 10 aircraft.

The radar has been approved for use by **Canada**, **Italy**, **Kuwait**, **Saudi Arabia**, the **United Kingdom**, and the **United Arab Emirates**, increasing the sales potential of the radar to these countries.

Forecast Rationale

Focus Shifts Away from Production; Maintenance Outlook Strong

With the delivery of the last APG-73 in June 2006, Raytheon's focus has shifted from production to maintenance, a market that could be quite lucrative. As radar systems become more complex and expensive, more countries will chose to maintain and even upgrade systems already in service rather than purchase new ones. Raytheon's APG-79, which itself is an upgrade of the APG-73, is taking over the market once held by its predecessor. The U.S. Navy, along with many other operators of the F/A-18 Hornet, is choosing the APG-79's AESA technology over the APG-73's older mechanical array.

The RAAF upgraded its F/A-18C/D fleet with the APG-73(V) during a fleet-wide retrofit, but many countries may favor the newer APG-79(V). Notably, the APG-73 can be upgraded with electronically scanned array technology.

Overall, maintenance will account for most of the funding applied to the APG-73 program. The last delivery was made in June 2006. At this point, signing a new contract would most likely mean restarting the production line. Considering the desirability of AESA technology, it is unlikely a country seeking new radar systems would undertake the costs of restarting production of a mechanically scanned array system. At this time, Forecast International believes there will be no new sales of the APG-73, despite a continuous stream of maintenance and upgrade contracts. Therefore, this report will be archived in 2008.

Ten-Year Outlook

No new production of the APG-73 is expected. Barring the award of new production contracts, this report will be archived in 2008.

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