

ARCHIVED REPORT

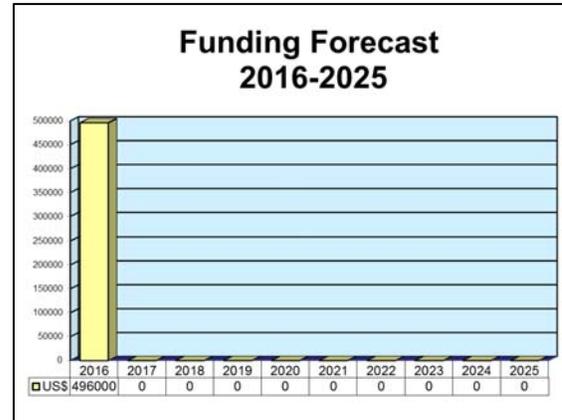
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APS-145(V) (E-2C)

Outlook

- The next-generation E-2, the E-2D, has begun production with a new radar
- Production of the APS-145 has ended
- 2016 is the final year for which the APS-145 will be funded. This report will be archived in 2017



Orientation

Description. High-power, UHF, Doppler early warning radar with a large rotating, circular radome.

Sponsor

U.S. Navy
 Naval Air Systems Command
 NAVAIR HQ
 47123 Buse Rd Unit IPT
 Patuxent River, MD 20670-1547
 USA
 Tel: + 1 (301) 342-3000
 Website: <http://www.navair.navy.mil>

Status. In service, in production, with ongoing logistics support.

Application. Advanced airborne surveillance radar for the E-2C Hawkeye, P-3 AEW&C, and C-130.

Price Range. In 1999, the price to retrofit a Block II suite for an E-2C was \$42 million per unit. Because the APS-145 is the most significant part of the Block II upgrade, it constitutes the largest portion of the total price.

In 2010, Lockheed Martin received \$42.95 million for each APY-9 unit acquired to equip E-2Ds. The APY-9 is the APS-145's successor, making comparisons between the prices of the two apt.

Based on this information, the price of a full APS-145 suite currently ranges between \$30.0 million and \$35.0 million.

Contractors

Prime

Lockheed Martin Mission Systems and Training, Syracuse Unit	http://www.lockheedmartin.com/us/mst.html , 6417 Deere Rd, Syracuse, NY 13206-1304 United States, Tel: + 1 (315) 456-0123, Prime
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Subcontractor

L-3 Communications - Randtron Antenna Systems	http://www.l-3com.com/randtron/ , 130 Constitution Dr, Menlo Park, CA 94025 United States, Tel: + 1 (650) 326-9500, Fax: + 1 (650) 326-7474 (Total Radiation Aperture Controlled Antenna Rotodome)
North Star Scientific Corporation	http://www.nsshawaii.com , 91-238 Kaleloa Blvd, Ste A, Kapolei, HI 96707-1847 United States, Tel: + 1 (808) 682-4100 (Radar Trigger Pulse Amplifier)

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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

	<u>Metric</u>	<u>U.S.</u>
Dimensions		
Rotodome	0.76 x 7.32 m	2.5 x 24 ft
Antenna weight	772 kg	1,700 lb
Characteristics		
<u>APS-145(V)</u>		
Frequency	400 to 450 MHz (in 16 selectable bands)	
Peak power	1 MW	
Pulse width	13 µsec	
PRF	300 pps (3 variables to reduce "blind speed" problems)	
Scan rate	5 rpm	
Beam	7° x 20°	
Radar range	350 nm - (large target) 145 nm - (cruise missile)	
Target capacity	2,000 simultaneously	
Sortie duration	4.5 hr typical	
<u>E-2C</u>		
Speed	300+ kt (552 kmph)	
Ceiling	30,000 ft (9,100 m)	
Crew	Five	

Design Features. The E-2 Hawkeye carrier-based surveillance aircraft has carried the APS-125/138/139/145(V) family of airborne surveillance radar systems for decades. The improved version, known as the APS-145, equips the E-2C Hawkeye and Hawkeye 2000. The system combines the basic radar and a new antenna system, known as the Total Radiation Aperture Control-Antenna (TRAC-A), into a configuration that enables the E-2C to operate in heavier jamming. Lockheed Martin increased the operating range by 40 percent and surveillance space volume by 96 percent, making it possible to monitor, track, and display more than 2,000 tracks simultaneously.

The APA-171(V) antenna system is housed in a rotating radome mounted on top of the aircraft. An identification friend or foe (IFF) array is incorporated into the radome. A three-channel rotary joint was

replaced by an eight-channel unit to permit more access to antenna signals, providing automated cues to the operators on the best radar mode for different jamming levels and directional information on the jamming sources. Directional information aids interception by battle group fighters. The radar and automated data processing can handle more than 600 tracks.

The APS-145(V) has sophisticated electronic counter-countermeasures (ECCM), and its adaptive signal processing provides effective target detection and tracking in complex target environments. The advanced radar incorporates automatic performance optimization that adapts to operating conditions over varied terrain. It monitors the radio frequency environment and selects the clearest operating frequency.

Other improvements included additional anti-jam antennas and an enhanced high-speed processor that

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doubled the E-2C's Group 1 processor capability. The new computers use parallel processing to boost speed and capability, while seven-color displays present 2,000 tracks on an 11-inch flat-panel screen, a significant improvement over the old monochrome system. With the new displays, operators have more flexibility in overlaying maps and displaying data in movable windows.

The upgrade included IFF improvements. Changes accommodate the radar's longer-range operation. Automatic interrogation is possible, and a jamming strobe alerts operators to ECM attempts. Enhancements to the Group II E-2C will make it possible for the Hawkeye to remain in service beyond 2015.

Operational Characteristics. The E-2C Hawkeye, the Navy's all-weather, carrier-based tactical warning and control system aircraft, provides all-weather airborne early warning and command & control functions for the carrier battle group. Additional missions include surface surveillance coordination,

strike and interceptor control, search-and-rescue guidance, and communications relay. An integral component of the carrier air wing, it uses computerized sensors to provide early warning, threat analyses, and control of counteraction against air and surface targets. During operations in Kosovo, E-2Cs operated more as battle managers than airborne early warning platforms, introducing a new concept of use.

Over land, the radar can track aircraft over most terrain and ground vehicles when the target density is relatively low. At sea, the APS-145(V) can track all significant naval targets (from large ships to fast patrol boats to stationary platforms) in most sea states.

High-altitude flight allows the battle group radar horizon to extend well beyond that of surface ship sensors – a significant part of naval tactical planning. The system automatically modifies track processing as required to maintain track integrity at land-sea interfaces. Beyond-the-horizon targeting has made the Hawkeye the sensor heart of the Navy's CEC program.



E-2C Hawkeye

Source: U.S. Navy

Variants/Upgrades

Mission Computer Upgrade (MCU). This upgrade replaced the L-304 processor with a DEC 2100 333-MHz commercial off-the-shelf (COTS) processor. The new computer is half the weight and one-third the size of the replaced system, with an order-of-magnitude improvement in performance.

Advanced Control Indicator Set (ACIS). The new, state-of-the-art COTS tactical workstation leveraged technology from the UYQ-70(V) Advanced Display System. It has a 16-foot high-resolution flat-panel display (with a growth capability to 21 ft during production).

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Cooperative Engagement Capability (CEC). A cooperative engagement processor, a digital distribution system, and a steerable end-fire antenna are installed. Onboard sensor data are input into the Fleet CEC network.

Satellite Communications. The HF, VHF, UHF, JTIDS communications suite was expanded with a fully integrated satellite communications terminal to extend Hawkeye operations beyond line of sight. It was planned for growth to full data capability.

Vapor Cycle Upgrade. This is a new, environmentally friendly cooling system for the onboard electronics.

Mission Computer Upgrade Program. Northrop Grumman completed upgrades to the Fleet Group II E-2C aircraft, integrating company avionics technology with commercial hardware. The Mission Computer Replacement Program replaced 1960s-vintage hardware

that had reached the extent of its processing and memory capacity. The solution was the Reconfigurable Processor for Legacy Avionics Code Execution (RePLACE) technology and open-systems COTS hardware. RePLACE had been developed by Northrop Grumman to solve the global problem of upgrading aging, slow, and unreliable processors without having to rewrite legacy software.

The RePLACE processors enable legacy software to run 20 to 100 times faster on state-of-the-art hardware. The upgrade increased mean time between failures (MTBF) to over 8,000 hours, reduced weight from 700 pounds to 105 pounds, lowered heat dissipation from 1,700 watts to 80 watts, and decreased CPU load time from over 2.5 minutes to less than 30 seconds.

Advanced Hawkeye. This is a near-complete rebuild of the E-2C Hawkeye, and has been redesignated the E-2D. This aircraft is equipped with a new electronically scanned radar dubbed the APY-9.

Program Review

In 1991, APS-145(V) radar installations began on Northrop Grumman E-2C Hawkeyes. The DoD terminated the E-2C production line for the Navy in FY93, a year earlier than originally scheduled, citing a declining defense budget. The Navy had planned to seek six E-2Cs in FY93. Without continued production, the Navy would be forced to proceed with massive upgrades and the reworking of its existing aircraft.

Decision Reversed

In 1994, the Navy reversed its production termination decision and announced that it was considering buying another 16 E-2Cs after 2000, in addition to the extra 20 aircraft it purchased between 1995 and 2000. The Navy determined that procurement of new-production E-2Cs was more cost-effective than a massive upgrade of the existing fleet.

In 1993/1994, Northrop Grumman and the Navy began a series of additional upgrades. Enhancements investigated or initiated included a new mission computer, an improved APX-100 IFF, a GPS, a satellite communications terminal, the Joint Tactical Information Distribution System (JTIDS), new workstation-based mission displays, and the integration of a Cooperative Engagement Capability (CEC).

In 1997, Japan requested the modification and upgrade of 13 E-2C Update Group II Mission Suite retrofit kits, to include the APS-145(V) (Category XXI) radars to replace APS-138(V) radars then in service. A February 1998 *Commerce Business Daily* notice announced a \$31 million basic ordering agreement for

E-2C Group 0 to II upgrade kits and installation data packages for the government of Japan.

Hawkeye 2000 First Flight in 1998

Beginning in 1998, the aircraft carried an improved IFF system, a new mission computer, new workstations, an ASN-139(V) navigation system, flight control upgrades, and a cooling system upgrade.

The first flight of the new E-2C Hawkeye 2000 occurred in April 1998. In 1999, the Navy approved multiyear procurement of 22 Hawkeye 2000 aircraft. Northrop Grumman then ordered 22 APS-145(V) radars from Lockheed Martin under a contract valued at \$100-\$140 million.

During the Dubai 2000 International Aerospace Exhibition, Northrop Grumman's Integrated Systems and Aerostructures sector announced a teaming with the U.S. Navy to upgrade E-2Cs with production mission systems based on the Hawkeye 2000 configuration for countries that procured them through Foreign Military Sales (FMS) programs. Northrop Grumman would take the aircraft and add the latest mission systems and radar, significantly upgrading the nation's AEW&C capability for less than the cost of a new Hawkeye 2000.

The U.S. Navy plan to upgrade its Hawkeye fleet created this opportunity. Because of the different environments of carrier-based versus land-based operations, the U.S. found that it was not cost-effective to upgrade its fleet of E-2Cs, and decided to procure new-production Hawkeye 2000 aircraft instead. The

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land-based airframes in service with allies have significant service life left, making upgrades economically feasible. This plan makes it possible for users to acquire advanced AEW systems and benefit from Navy-funded upgrades. It would also improve interoperability between the Navy and its allies.

The first production Hawkeye 2000 was delivered to the U.S. Navy in October 2001. In April 2002, the third Hawkeye 2000 production aircraft was delivered to the Navy.

Egypt and Japan Upgrade to APS-145

Egypt and Japan had announced a desire to upgrade to Hawkeye 2000 standards. Egypt would replace the APS-138(V) with the APS-145(V), upgrade the mission computer, and add new workstations. The related contract was valued at \$138 million. Work on the first Egyptian aircraft began in late 2002.

In November 2000, Japan ordered two additional upgrade kits and associated services to upgrade its fleet to the Hawkeye 2000 standard. The contract to upgrade the entire fleet was put at \$400 million; the upgrades were to be performed over five years, with completion of the first modified E-2C planned for 2004. The modifications would take place at Kawasaki Heavy Industries. Because Japan flies its E-2Cs from land bases, the aircraft have twice the service life of U.S. Hawkeyes. These upgrades should extend the service life of Japan's fleet to 2020.

UAE Seeks Newer Aircraft

In September 2002, the United Arab Emirates requested five refurbished E-2C aircraft upgraded to the Hawkeye 2000 configuration. The request included five APS-145(V) radars. However, the UAE then decided to pursue other options. In November 2009, the UAE

signed a contract with Saab for two Saab 340 AEW systems, which consist of the Saab Erieye radar mounted on a Saab 340 aircraft.

Antenna Contract

In October 2003, L-3 Communications' Randtron Antenna Systems Division was awarded a \$65 million contract by Northrop Grumman to provide the next-generation AEW radar antenna for the E-2C Hawkeye. Procurement of a full 75 aircraft could bring the value of the contract to over \$300 million.

Pakistan Purchasing P-3s

In December 2006, Pakistan expressed interest in purchasing three excess P-3s modified with the E-2C Hawkeye 2000 AEW suite. France, meanwhile, is interested in a used E-2C. While Pakistan's order includes new-production AEW suites, France's order does not.

The following month, Lockheed Martin was awarded a \$186.5 million contract modification for seven P-3 aircraft missions systems, including an inverse synthetic aperture radar (ISAR), electronic support measures (ESM), an electro-optical/infrared (EO/IR) system, and an intercommunication system (ICS). The FMS order was for the government of Pakistan.

Make Way for the Advanced Hawkeye

The E-2D Advanced Hawkeye has replaced the APS-145's primary platform, the E-2C Hawkeye. The U.S. Navy took delivery of its last production E-2C Hawkeye 2000 aircraft in September 2009, and the first E-2D Advanced Hawkeye was delivered to Norfolk Naval Air Station in July 2010. The E-2D is equipped with the Lockheed Martin APY-9 radar.

Contracts/Orders & Options

(Contracts over \$5 million.)

<u>Contractor</u>	<u>Award (\$ millions)</u>	<u>Date/Description</u>
Northrop Grumman	576.5	Jan 2004 – Modification to convert a previously undefinitized multiyear contract action to a definitized multiyear contract for FY04-FY07 procurement of three Hawkeye 2000 (HE2K) aircraft and five trainer E-2Cs, plus associated equipment and support. In addition, one HE2K and one E-2C trainer were to undergo System Development and Demonstration. Completed Sep 2009. (N00019-03-C-0044)
Northrop Grumman	14.0	Mar 2005 – FFP delivery order against a previous basic ordering agreement for the manufacture of engineering change proposal kits for the E-2C Group 0 Hawkeye (ECP-422-R1, Kit 9, 15-ton enhanced vapor cycle, and ECP-411-R1 200 export configuration upgrade for the government of Japan under FMS). Completed Dec 2007. (N00019-04-G-0003)

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<u>Contractor</u>	<u>Award (\$ millions)</u>	<u>Date/Description</u>
L-3 Communications	6.1	Dec 2006 – Not-to-exceed order under a previously awarded contract (N00383-06-G-072B) to repair E-2C TRAC-A rotodome antenna assemblies. Completed Sep 2008.
Lockheed Martin	186.5	Jan 2007 – Ceiling-priced modification to a previously awarded IDIQ FMS contract for seven P-3 aircraft missions systems for Pakistan. This mod includes a fully capable ISAR, ESM, acoustic system, EO/IR system, and ICS. In addition, this mod includes installation of P-3 mission systems into the aircraft. Work was to be completed in Jul 2011. The Naval Air Systems Command, Patuxent River, MD, was the contracting activity. (N00019-06-D-0012)
Northrop Grumman	8.5	Jan 2009 – CPFF delivery order against previously issued basic ordering agreement (N00421-05-G-0001) to provide three system interrogator / transponder set RT1645 weapon replaceable assemblies and five shop replacement assemblies for Japanese FMS E-2Cs. Work was completed in Dec 2010.
L-3 Communications	7.1	Jan 2009 – Not-to-exceed delivery order under previously awarded contract N00383-06-G-072B to repair TRAC-A rotodome antenna assemblies in support of the E-2C. Work was expected to be completed by Mar 2011.
Lockheed Martin	44.0	Nov 2009 – Modification to a previously awarded IDIQ FMS contract for the upgrade of seven Pakistan Navy P-3C aircraft. This program replaces obsolete and unsustainable avionics with modern equipment that provides increased capabilities and reliability, and that will be sustainable. Work was completed by Feb 2013. (N00019-06-D-0012)
Lockheed Martin	34.0	Dec 2009 – Modification to a previously awarded IDIQ FMS contract to provide additional funding for P-3C mission system spares for Pakistan. Work was completed in Sep 2011. (N00019-06-D-0012)
Northrop Grumman	6.1	Jan 2010 – FFP, CPFF delivery order against a previously issued basic ordering agreement to provide engineering, technical, and sustaining services in support of Taiwan Air Force E-2C aircraft. Work was completed in Jan 2011. The Naval Air Systems Command, Patuxent River, MD, was the contracting activity. (N00421-05-G-0001)
Lockheed Martin	7.3	Dec 2010 – Modification to a previously awarded IDIQ FMS contract for services for the Pakistan Navy's P-3C upgrade program. Support included labor, aircraft hangar costs, and the acoustic receiver technical refresh program report resolution required to upgrade and overhaul seven P-3C aircraft. Work was completed in Nov 2011. The Naval Air Warfare Center Aircraft Division, Lakehurst, NJ, was the contracting activity. (N00019-06-D-0012)
Lockheed Martin	37.6	Jun 2011 – Fixed-price-requirements contract for repair of items to support the APS-145 radar for the E-2C aircraft. Work is expected to be completed by Jun 2016. The Naval Inventory Control Point, Philadelphia, PA, is the contracting activity. (N00383-11-D-006N)
North Star Scientific	10.49	Jun 2011 – FFP delivery order against a previously issued basic ordering agreement for the production of 83 APS-145 Radar Trigger Pulse Amplifier Redesign (TPAR) WRA-31 units, 74 spares, and technical items for the E-2C, and one modified TPAR unit for the E-2C aircraft simulated maintenance trainer. Work was to be completed by Dec 2013. (N00019-10-G-0008)

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<u>Contractor</u>	<u>Award (\$ millions)</u>	<u>Date/Description</u>
L-3 Communications, dba Randtron Antenna Systems	6.74	Mar 2013 – Contract under previous basic ordering agreement for repair of the TRAC-A rotodome antenna and IFF Mode 5/S upgrade of four of the French Navy's E-2C TRAC-A antennas, as well as overhaul of TRAC-A rotary coupler assemblies and IFF Mode 4/S upgrades for six rotary couplers. Work was completed by Mar 31, 2015. The contract involved U.S. FMS using French Navy funds. (N00383-11-G-004N)

Timetable

<u>Month</u>	<u>Year</u>	<u>Major Development</u>
	1988	USN begins APS-145(V) integration on E-2C
	1989	APS-145(V) production initiated
	1991	APS-145(V) IOC; deliveries begun; first flight of EC-130V
Mar	1992	Taiwan initiates E-2C procurement (four aircraft)
	1995	Taiwan's E-2Cs arrive in country
Mar	1995	France initiates two-aircraft procurement
	FY96	First CEC developmental units received
	FY98	CEC LRIP; Radar Modernization Program begins; Japan initiates upgrades
Apr	1998	First French E-2C delivered; first Hawkeye 2000 flight
	1999	End of Group 2 upgrade program; Egypt initiates upgrades
Apr	1999	French contract for third aircraft
Sep	1999	First APS-145(V)-equipped P-3 delivered to U.S. Customs Service
	1999	Taiwan initiates fifth and sixth aircraft purchase; Egypt announces upgrade to APS-45(V)
Oct	2001	First Hawkeye 2000 delivered
	FY01	EMD of RMP; ground demo of E-2C improvements; PDR
3Q	2001	IRST demo; LADAR demo; multisource/multisensor integration; radar modernization CDR
	FY02	Hawkeye 2000 IOC; Advanced Hawkeye development begins
2Q-4Q	FY02	MSI Phase 1 development
3Q-4Q	FY02	C-130 RMP IACO
4Q-2Q	FY02-03	C-130 flight test
	2003	Third French E-2C delivered
1Q	FY03	MSI Phase 1 S&T demo
1Q-4Q	FY03-04	IPAD development
1Q-4Q	FY03-05	SIAP Block 0
1Q-4Q	FY04	MSI Phase I FQT
3Q	FY04	AODS S&T demo, MSI Phase II JTFX
4Q-4Q	FY04-05	AODS FQT
1Q-4Q	FY04-07	ABC2 development
1Q-4Q	FY04-07	MSI Phase II FQT
1Q	FY05	HF SIPRNET fleet prototype
3Q	FY05	ABC2 Talisman Saber
4Q	FY05	AODS Deploy, SIAP Blk 0 Deploy HE2K
1Q	FY06	ABC2 Trident Warrior, JEFX
3Q	FY06	MSI Phase II JTFX
4Q	FY06	AODS Interim S/W to AHE
3Q	FY07	MSI Phase II Interim Deploy HE2K
Oct	2009	First refurbished P-3C aircraft for Pakistan delivered
	2014	Completion of Pakistan's P-3C upgrade program
	FY16	Expected completion of U.S. Navy E-2C radar improvement upgrade

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Worldwide Distribution/Inventories

Egypt. The Egyptian Air Force operated a fleet of five E-2C Hawkeyes upgraded with the APS-145 Group II mission suite.

France. The French Navy is procuring two Group II aircraft and one Hawkeye 2000, and has announced interest in buying more. The Group II aircraft will eventually be upgraded to the Hawkeye 2000.

Japan. The Japan Defense Forces operate 13 Group 0 E-2Cs originally equipped with APS-125/138s. They are upgrading to the Hawkeye 2000.

Pakistan. Pakistan ordered seven P-3C Orion aircraft upgraded with the APS-145 radar.

Singapore. Singapore has four E-2Cs.

Taiwan. The Republic of China has completed an FMS order for four APS-145(V) radars plus significant spares to equip its Group II E-2C aircraft. In 1999, officials announced the possible sale of two additional E-2T Hawkeye 2000E aircraft.

The **United States** operates the APS-145 on Navy E-2C Hawkeye 2000s and U.S. Coast Guard P-3B AEW aircraft.

Forecast Rationale

In 2014, production of the APS-145 ended. Production is not likely to be restarted.

In the next generation of the E-2 Hawkeye – the APS-145's main platform – the radar has been replaced by the APY-9. This makes future sales of the older radar unlikely.

2016 will constitute the final year of O&M funding, although E-2C operation is expected to be sustained through 2020. The APS-145 report will be archived in 2016.

Ten-Year Outlook

ESTIMATED CALENDAR YEAR O&M FUNDING (in US\$)												
Designation or Program	High Confidence					Good Confidence			Speculative			Total
	Thru 2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	
MFR Varies												
APS-145 <> United States <> Navy <> E-2C 005-11 Radar Improvement Program												
	31,651,586	496,000	0	0	0	0	0	0	0	0	0	496,000
Total	31,651,586	496,000	0	0	0	0	0	0	0	0	0	496,000