

US Navy E-2 Hawkeye



Right: Illustrating the three different versions of the aircraft in service - US Navy E-2D 168275 'AD-671' and E-2C Hawkeye 2000 166503 '661' from VAW-120 'Greyhawks' and E-2C Group II Nav Upgrade Hawkeye 165299 'AB-600' from VAW-123 'Screwtops' join up over the Atlantic Ocean. All photos Ted Carlson/ Fotodynamics unless stated

Today's legacy Hawkeye version, the E-2C, became operational in 1973 and surpassed one million flight hours in August 2004. Over the years, several upgrades have been applied to the C-model's active and passive sensors, engines and propellers, and the ultimate E-2C variant, the Hawkeye 2000, features a new mission computer, improved radar displays and Cooperative Engagement Capability (CEC). Combined with the shipboard Aegis Combat System, the latter forms the cornerstone of the navy's sea-based Integrated Air and Missile Defense (IAMD).

The Hawkeye's Airborne Tactical Data System (ATDS) encompasses the radar (housed in a prominent 24ft/7.3m dish turning at six rotations per minute), airborne computers, plus a memory and data link system. This is connected directly to the Naval Tactical Data System (NTDS), which creates an overall picture of the tactical

situation within the area of operations.

The aircraft's five-man crew consists of two pilots and three equipment operators. The equipment operators are able to monitor multiple contacts at any given time, direct

strike aircraft to assigned targets in all weather conditions, while maintaining a watch for hostile forces. Working as a team, the Hawkeye provides the fleet with its early warning umbrella, capable of directing air defences against any adversary. Thanks to a glass cockpit, the pilots have access to the same information as the operators in the rear of the aircraft, improving situational awareness.

Expanding the eye of the fleet

The E-2 Hawkeye has proven to be a very reliable airborne early warning and control (AEW&C) platform for the US Navy over the past decades. **Patrick Roegies, Jurgen van Toor and Ben Gorski** describe the new capabilities that will sharpen the 'eye of the fleet'.

The E-2C and Hawkeye 2000 share the same radar capability and can detect targets anywhere within a surveillance envelope of three million cubic miles while simultaneously monitoring maritime traffic. A single Hawkeye can perform all-weather patrols, automatically and simultaneously tracking more than 600 targets, and controlling more than 40 airborne intercepts.

The Hawkeye platform is in continuous development and recent deliveries of the latest E-2D are the next step in enhancing its capabilities. Such are the changes manifest in the D-model that the tasks appointed to the aircraft and aircrew are different and the use of the Hawkeye within the carrier air wing has been redefined.

The E-2C was not designed to scan small

objects over a cluttered land environment, but to track larger targets over water using the AN/APS-139 radar, later superseded by the APS-145.

However, the E-2D's latest AN/APY-9 radar offers new capabilities and can be operated in different modes. The crew can electronically steer the beam inside the dome – it can be compared to sitting on a rotating chair while your head remains focussed on a certain object. It allows the Hawkeye to send a lot more electrons downrange and receive more information in return.

It's also possible to lock the radome in a fixed position. Instead of six rotations per minute resulting in an update every 10 to 12 seconds, the system can increase the update rate within a specific area, boosting detection and tracking capability.

With the radome locked down, the Hawkeye isn't performing its primary mission of 360° surveillance to protect the carrier battle group. This is one reason why two Hawkeyes may be launched, allowing one to perform a more specific search with radome locked. ▶

Carrier deployments

An E-2 deployment on an aircraft carrier comprises either four E-2Cs or five E-2Ds. The aircrew of an embarked E-2C squadron consists of 25 personnel, increasing to 35 for a deployed E-2D unit.

CDR Jason Fox, chief staff officer with the Airborne Command & Control and Logistics Wing at Naval Air Station Point Mugu, California, explained that an embarked Hawkeye squadron typically has three aircraft on the flight deck. Four or five E-2s on deck involves intricate choreography to move the 'big wing' aircraft around, and it's more practical to keep one or two aircraft in the hangar deck where they can undergo preventive maintenance or repairs.

Having five aircraft on the carrier also supports operating Hawkeye two-ships, which is the norm today. This provides redundancy – for example, if one aircraft has a malfunctioning radar or identification friend or foe (IFF) system, the other can fill in. More importantly, two aircraft offer the capacity to dynamically 'flex' between different missions.

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1 The second Advanced Hawkeye, E-2D 166502, AA-2, cruises over the Atlantic during a test mission. The additional air scoop on top of the fuselage, located above the larger intake, and the flush finish of the upper radome, are distinguishing features of the latest D-model Hawkeye. **2** A member of the Hawkeye aircrew from VAW-116 'Sun Kings' heads out to his aircraft for a mission from Point Mugu, California. Point Mugu's Naval Base Ventura County is home to ten squadrons of Hawkeyes under the Commander, Airborne Command & Control and Logistics Wing (COMACCLOGWING). Patrick Roegies **3** Seen on the apron at Point Mugu with its wings folded, E-2D 169071 '661' is assigned to VAW-120 'Greyhawks', the fleet replacement squadron, and makes an interesting contrast with E-2C Hawkeye 2000 166503 - also coded '661' - in this article's lead image. Patrick Roegies **4** The first of the Advanced Hawkeyes, AA-1, E-2D 166501, departs St Augustine, Florida, for a test mission. The E-2D is powered by improved Allison T56-A-427A engines with full-authority digital electronic control (FADEC) and one-engine auxiliary power reserve mode. **5** The smart-looking 'boss bird' of VAW-121 'Bluetails' is E-2D 168592 'AG-600'. The squadron operates five Advanced Hawkeyes as part of Carrier Air Wing 7 and deploys on board the USS 'Abraham Lincoln' (CVN 72). Melvin Jansen



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However, the E-2D's huge increase in capability means that it's not only defending a strike group but operating as an airborne battle-management platform in a net-centric environment. This development puts additional demand on the squadrons, that can be met by having an additional aircraft airborne.

Expanding footprint

With the introduction of the E-2D, the demands on the platform were increased and the navy settled upon a five-aircraft E-2D squadron compared with four for the E-2C. Coalition operations of the recent past - including Iraqi Freedom, Inherent Resolve, Enduring Freedom and Operation Southern Watch - reinforced the need for airborne command-and-control platforms beyond those offered by the USAF. This increased the burden on the E-2, as Hawkeye squadrons were called upon to support both the carrier group and wider joint forces.

A typical day at sea

While on deployment, a daily Hawkeye mission usually starts with two to three hours of mission planning. This includes examining maps to determine the geographical position of the carrier, looking at airfields within range to establish awareness of other aircraft, as well as assessing the presence of ships - referred to as 'contacts'. Depending where the carrier is sailing, some of these air or surface contacts may be hostile.

Next, the crew visits all the ready rooms of the various squadrons on board. During these briefs the Hawkeye crew gathers information on

the daily operations. For example, each strike fighter unit will have its mission for the day and takes the E-2 crew through the plan - these are published and discussed on a daily basis to establish who is flying with the Hawkeye on that particular mission. The Hawkeye crew can also brief the other squadrons on possible capability limitations they might have during that mission. This process takes roughly two to three hours.

When all the squadrons have been visited and consulted, the mission brief for the E-2 crew takes place, lasting approximately an hour. If a large-force exercise is scheduled, an additional briefing is needed, involving all the aircrews for that mission - adding roughly another hour.

With the pre-flight briefing complete, the crew heads for the flight deck to inspect, embark and start the aircraft. Preparations to launch take another hour. Usually three Hawkeyes are positioned on the flight deck. With one or two Hawkeyes in the maintenance bay and one spare on the flight deck, two E-2s will be launched. Typically, the Hawkeye will be 'first off, last down' for any mission and this also creates space on the deck for the jets to launch.

A typical peacetime mission lasts roughly four hours. Depending on the carrier's geographical location, if it's in an area where no threats are expected, there's no actual requirement to launch a Hawkeye. When the carrier is near a coastline, deployment of an E-2 is considered necessary to prevent other aircraft from flying over the carrier.

In standard operating conditions a single Hawkeye is sufficient to perform the designated



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tasks but having a second example airborne has proved to be more efficient. This enables the air wing to focus on a specific operational area or provide recovery overwatch in case an aircraft is in trouble.

When the E-2 has safely returned to the deck, another two hours of mission debrief conclude the day's work. Once again, a large-force exercise will add another hour to the debrief and bring together all the crews involved.

All told, an operational mission for a deployed E-2 aircrew at sea involves a working day of roughly 11-12 hours. After performing their daily tasks, the crews rest before the

next cycle. A minimum of eight hours of sleep is mandatory during peacetime. In a conflict situation, 18-hour mission times are sanctioned with only four hours of sleep in between, but after each of these, 15 hours of rest is required to prevent physical burnout.

Aircrew cycles

Besides performing daily flying operations, a Hawkeye squadron has dozens of extra tasks and commitments. This influences the composition of the aircrews as well. Keeping one particular aircrew together is very difficult, and a rotational system generally proves more practical.

Additional tasks assigned to the E-2 unit include having a daily squadron duty officer, a landing signals officer (LSO) and a Carrier Air Traffic Control Center (CATCC) representative – or 'tower flower' – who deals with any emergency situations with an aircraft. Although the air officer ('air boss') responsible for all aspects of aircraft operations is familiar with most of the types, they are not a subject matter expert, so require additional, specific input from the 'tower flower'.

As a result of these extra duties, aircrew composition is often subject to change during peacetime. But their training focuses on ▶



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Above: Probe-equipped E-2D 169061 'JA-600' is one of the aircraft operated by Air Test and Evaluation Squadron 1 (VX-1) based at Naval Air Station Patuxent River, Maryland. Changes made to the E-2D for in-flight refuelling include a fixed probe and associated plumbing, formation lighting, long-endurance seats, as well as flight control software and hardware changes. Hans Antonissen

standardisation, so everyone should perform their tasks in the same manner. Speaking to AFM, CDR Jason Fox, chief staff officer with the Airborne Command & Control and Logistics Wing, recalled that during his time as a squadron executive officer at the weapons school, the mantra of all weapons and tactics instructors was that each crew member should be able to operate any of the aircraft, regardless of unit or fleet, at any time.

However, CDR Fox noted that during Operations Iraqi Freedom and Enduring Freedom, the E-2 squadrons were essentially operating as 'combat crews.' These consisted of the same five individuals and had the advantage of all personnel having the same daily rhythm, ensuring sufficient sleep and rest. Although all crews are trained to perform 'plug-and-play' missions, this helped them get to know each other and learn to anticipate each other's actions.

Battle management role

As designed, the Hawkeye was a single-sensor platform that typically went out and operated on its own. But in the last decade it has developed into a central information-gathering and relay station and gained a battle management role. The Hawkeye's Link 16 capabilities mean it can communicate with and co-ordinate all US military assets – and most of those in a coalition. The aircraft is now a key node in that tactical

data-link network. While the E-2 still flies its mission in the rear area of operations, it can communicate with the frontline forces and has become the 'manager' within this network.

Besides communicating with warships and fighters, the Hawkeye can also exchange information with other, similar platforms, such as the E-3 AWACS and other AEW&C aircraft on the Link 16 network.

Information gathered is relayed to any asset that needs to receive it. Data can be transmitted securely using different levels of cryptology that can be configured in multiple ways. While anyone might be able to receive the data, they will be unable to use it without the correct crypto key.

Although land-based, the US Navy's P-3 and P-8 Poseidon are also increasingly working in a battle management role. The Hawkeye, however, retains a unique air search and surface search capability. "They are apples and oranges," explained CDR Fox, "but they are complementary to the battle group." While the E-2 is unable to perform anti-submarine warfare tasks, beyond detecting a surfaced submarine, the E-2 is able to manage the P-3 and P-8 using both voice communications and digital data links.

For example, a P-3 or P-8 may have launched eight hours previously from a shore-based location and then transited to the assigned

area of operations. An E-2, launched from the carrier an hour ago, will have been communicating with the carrier battle group's anti-submarine commander about a possible contact in this area. The E-2 can then brief the P-3 or P-8. Both crews work very closely together to ensure as much as information as possible is shared between the assets.

Converting to a new E-2 subtype or introducing a modification is a delicate process implemented on a squadron-by-squadron basis. Each new function or piece of kit undergoes developmental test and then moves to operational test under the watch of experienced Hawkeye crews. As a change is introduced, the squadrons look to modify the doctrine, training materials and facilities. The work required of the unit to introduce the new capability is prepared in detail at the Carrier Airborne Early Warning Weapons School (CAEWWS), also known as TOP DOME, located at NAS Fallon, Nevada. Regular exchange of information with the developmental and operational test pilots helps determine how the new capability will be used. Also at Fallon, the Naval Aviation Warfighting Development Center (NAWDC) is responsible for the tactics, techniques and procedures the crews will use, and develops clear instructions on how to perform the new task(s). NAWDC also trains the weapons and tactics instructors, who will transfer their knowledge to the squadrons.



Above: Now on strength with VAW-123 'Screwtops', E-2C Hawkeye 2000 165822 is seen in its previous guise as 'NG-601' with VAW-117 'Wallbangers'. This squadron continues to provide Hawkeyes to Carrier Air Wing 9 for deployment aboard USS 'John C Stennis' (CVN 74). Hans Antonissen **Right:** Operated by VAW-125 'Tigertails', E-2D 168593 'AB-601' rests between missions at NAS Chambers Field, Norfolk, Virginia. The 'Delta' Hawkeye is fast becoming ubiquitous among the VAW ranks and in February 2017 VAW-125 arrived at Marine Corps Air Station Iwakuni, Japan, replacing VAW-115 with Carrier Air Wing 5, supporting USS 'Ronald Reagan' (CVN 76).



Meanwhile, the weapons school for the Hawkeye – the Airborne Command & Control and Logistics Weapons School (ACCLWS) – has outposts on the east and west coasts. ACCLWS includes weapons and tactics instructors trained by NAWDC to provide training to the operational squadrons.

During conversion to a new subtype, the first unit to receive the aircraft is the Hawkeye fleet replacement squadron – Airborne Command and Control Squadron 120 (VAW-120) 'Greyhawks' – which is charged with training the future instructors.

From Charlie to Delta

CDR Fox explained some of the E-2D's many advantages compared with the E-2C. While the original analogue radar was designed to detect large, bomber-sized aircraft over water during the Cold War era, the D-model has evolved into an aircraft able to detect smaller objects, over greater ranges, in a high-clutter environment, over land and water.

The radar remains the primary sensor, but the communication suite is also updated to state-of-the-art technology. The E-2D offers considerable redundancy in terms of gathering and exchanging data – it can use VHF, UHF, HF and SATCOM to communicate if an adversary attempts to deny any of the electromagnetic spectrum.

The E-2D's electronic support measures (ESM) is a passive detection system that collects data and then fuses it with information from other sensors. It helps the crew interpret and understand the combat environment in terms of the electronic spectrum. Information gathered by the ESM system can be relayed to the battle group using Link 16, or more often via voice communications.

The navy's F-35C and EA-18G now also offer a passive detection capability and are able to fly more hazardous missions. But the E-2 makes a significant contribution to the electronic picture, improving on overall situational awareness for a better understanding of what's happening in the area of operations. ■

Inside the Hawkeye



Above: Inside the glass cockpit of an E-2D at Saint Augustine, Florida. On the left is LCDR Drew 'Balls' Ballinger and on the right is Tom 'Booty' Boutin. The E-2D co-pilot can also perform radar mission tasks, rather than just help fly the aircraft. Below: LT Dave 'Cabbage' Peterson working in the back of an E-2D. The Advanced Hawkeye has the more capable and further-reaching AN/APY-9 radar. The fully digital phased-array radar has demonstrated the ability to detect small targets, such as cruise missiles, at greater ranges than its predecessor, and also offers improved stability.



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Banking over Naval Air Station Oceana, Virginia, this is E-2C Hawkeye 2000 166503 of VAW-120. Hans Antonissen



Aerial refuelling capability

A first Hawkeye equipped with an aerial refuelling probe was delivered to VAW-120 last September 9. An air refuelling capacity had been under flight test since December 2016. The navy also undertook research into the development of a 'wet' wing, as another means of increasing range. This presented several challenges – among them weight constraints and additional stress on the airframe. While aerial refuelling eliminated the US Navy's requirement for a wet wing, it may be more useful for export operators and has been selected by Japan for its E-2Ds. Meanwhile, VAW-120 is gaining experience with the refuelling capability and developing a syllabus to train active aircrews and the next generation of pilots.

The E-2D's fixed refuelling probe is located directly over the centreline of the cockpit. CDR Fox explained that "it will increase the capability for time on station significantly, and it allows the Hawkeye to go further from the aircraft carrier". In its new configuration

the Hawkeye can be refuelled by most USAF and coalition tankers, as well as US Navy Hornets carrying a 'buddy' store.

Even with aerial refuelling, the E-2 is limited to a maximum operational time of ten hours. At this point, the aircraft oil needs changing, and the crew endurance will have reached its limit. Once plugged into the tanker, the fuel flow rate is high – it takes around six to eight minutes to receive a full fuel reserve from the tanker.

Aerial refuelling capability is only being implemented on the E-2D and plans call for one squadron per year to undergo the conversion. The fleet transition will start this year and is intended for completion around 2027-28.

Having tried it out in the simulator, CDR Fox said that "refuelling in a Hawkeye is not an easy task, since it is not originally designed [as a receiver]. The flight control system has been improved to help the crew out, but the two propellers are very close to the hose and can damage it easily if things don't work out as planned. It was the hardest thing I ever

had to do and, although it might be a little tougher in a simulator than it is in actual flight, since you will have a better feel for the aircraft and its performance, it took all of my experience and efforts to get the job done."

Navy Integrated Fire Control - Counter Air

Both E-2C and E-2D are linked to the Navy Integrated Fire Control - Counter Air (NIFC-CA) architecture, a framework that brings together 'sensors and shooters' as an upgrade of the Aegis system. Both versions of the Hawkeye can contribute to NIFC-CA, but, compared with the C-model, the E-2D can detect contacts at greater distances in more challenging environments, including smaller objects, such as cruise missiles. In its current configuration, the E-2C has difficulty tracking contacts in highly cluttered environments over land. Information is relayed to the battle group by both types, but the E-2D's new radar brings increased accuracy, power, detection and tracking of targets, making it an integral part of NIFC-CA.

The operating range of the E-2C and 'D' is roughly similar. The Hawkeye's range is around 1,000 miles (1,609km) and the introduction of aerial refuelling doesn't necessarily mean the aircraft will operate further from the carrier. Typically, the crew prefer to keep the carrier in radar range in order to defend it against any threat. That said, the E-2's role is changing. While CAEWWS was historically focused on early warning, the future for the Hawkeye includes connecting command chains as an 'airborne quarterback'. In the past, the E-2 was just another sensor, but it now has the ability to fuse data, co-ordinate the battlefield and make rapid decisions in a tactical environment.

The further a Hawkeye gets from the carrier, the less protection it can provide for the battle group, but a judgement will be made depending on the threat. During Operation Enduring Freedom, for example, Hawkeyes ranged far from the ship. The same would not necessarily apply when operating in the Persian Gulf or off the coast of Syria. On the other hand, stationing an E-2 further away means it can provide advanced warning to the battle group. With its increased capability, the Hawkeye's traditional link to the carrier threatens to be broken but the navy will surely fight hard





The 'double nuts' ('00') code worn by E-2C Hawkeye 2000 165648 'Elvis' indicates it's the 'CAG bird' of VAW-116. In October 2017 the 'Sun Kings' joined Carrier Air Wing 17 on board USS 'Theodore Roosevelt' (CVN 71) and flew missions in support of Operation Inherent Resolve, completing 812 sorties, 2,354 flight hours and 689 mishap-free carrier landings. Patrick Roegies

to keep the E-2 within the carrier air wing.

Eventually, all E-2Cs will be replaced by E-2Ds. A total of 75 are being purchased and the last C-models are due to be phased out around 2027-28.

VAW-113 'Black Eagles' became the first west coast squadron to receive the E-2D in August last year. It completed its transition at Naval Station Norfolk, Virginia, over a period of around three months, with training conducted by VAW-120. In the second week of September, VAW-113 qualified for safe-for-flight status, which means it's now allowed to operate the aircraft independently. The unit has reinstated the 'Eagle' callsign and repainted its first two E-2Ds. More importantly, the 'Black Eagles' maintainers are turning wrenches on the aircraft without VAW-120 oversight. Next in line is VAW-117 'Wallbangers', which began its transition in November/December. It is following the same procedure, by going out to VAW-120 at Norfolk for transition training. Conversion to the D-model started on the

east coast for logistic reasons, since that is where the test squadrons and the FRS are located. However, with a 'pivot' to the Asia Pacific region there has been a significant demand to get the aircraft into this area of operations as soon as possible. Once the east coast logistic chain was up and running, some of that effort was moved over to the west coast to aid its switch to the new aircraft.

Future developments

Advances in unmanned aircraft systems (UAS) will perhaps bring the next major change in the way the Hawkeye operates. It's a fundamental fact of warfare that the longer the lines of communications, the weaker they are. A UAS controlled from on board a ship represents a long line of communication, compared with a Hawkeye controlling the battlespace. At the same time, interpretation of sensor data is still best handled by humans, as is processing changes in the tactical situation. Furthermore, a human in an aircraft is still much harder to defeat

if the electro-magnetic spectrum is denied. While the carrier air wing will add drones in the future, the MQ-25 Stingray will initially be employed as a tanker, performing fairly simple circuits that don't require a human pilot on board.

CDR Fox compared the Hawkeye's current role to the early days of land warfare when a soldier on a hill collected information that was relayed to the general behind the front lines. That information allowed the general to determine strategy and tactics in order to control the battlespace. Unlike the soldier on the hill, today's E-2 crew rely on sophisticated systems to acquire that information, but they are still talking directly to the frontline troops and influencing the battle. **AFM**

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Above: An E-2C Hawkeye 2000, 166508 'NH-602' wears the markings of VAW-115 'Liberty Bells', which joined Carrier Air Wing 11 and USS 'Theodore Roosevelt' (CVN 71) in February 2018. VAW-115 was on board the carrier when it departed San Diego for a scheduled Indo-Pacific deployment earlier this year. Patrick Roegies
 Left: Another operator of the Hawkeye is the Naval Aviation Warfighting Development Center (NAWDC) at Naval Air Station Fallon, Nevada, which is responsible for the Carrier Airborne Early Warning Weapons School (CAEWWS), also referred to as TOP DOME - the E-2 weapon school. Among the aircraft it has flown is E-2C 164352 '601'. Patrick Roegies