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The Future of AWACS: Technological Advancement or Technological Relic?

by

Ernie Chen, Maj, USAF

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Advisor: Dr. Fred Stone

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TABLE OF CONTENTS

Page

ABSTRACT

The United States maintains one of the world's most successful Command and Control (C2) platform in the E-3 AWACS aircraft. The E-3 fleet, however, is aging rapidly and with rising operational costs and no source of sustainable replacement parts. The principal purpose of this research was to discuss the future of the Air Force's E-3 Sentry fleet and the potential replacement for the next generation AWACS. Several Airborne Early Warning (AEW) options were accessed, utilizing the evaluation criteria including the E-3, other AEW in production, and other potential AEW concepts. After a thorough research, both a short-term solution and a long-term solution was developed. The short-term solution is to the continual upgrade of the E-3G, and the long-term solution is to acquire a new AEW platform in the E-767. However, it is recommended that the Air Force pursue the purchase of the E-767. The E-767 provides the Air Force an easily upgradable platform while minimizing research and development costs associated with an entirely new platform.

INTRODUCTION

The United States operates one of the world's most successful Command and Control (C2) platform in the E-3 Sentry or Airborne Warning and Control System (AWACS) aircraft. Although there are other AWACS aircraft produced by other nations and companies, the E-3 Sentry is a battle-proven system that has been operational for forty years. The role of the E-3 is an integrated command and control battle management and surveillance platform providing an accurate, real-time picture of the battlespace to the Air Force leadership at the Combined/Joint Air Operations Center.[1] Developed in the late-1960s as a replacement for the propeller-driven Lockheed EC-121 Warning Star, the E-3 was based on the jet-propelled Boeing 707 airframe. Since declared operational in 1977, the E-3 has provided critical early warning and tactical C2 operations for joint leaders on the battlefield. Its effective employment in operations such as Desert Storm/Shield, Allied Force, and most recently Operation Inherent Resolve has demonstrated the AWACS as a valuable force multiplier, so much so that numerous other companies and nations have tried to replicate this capability. The E-3 Sentry is in service with five different organizations around the world. The Boeing 707 airframe, however, is no longer in production, and despite some improvements, the technology employed on the E-3 is still based on the original 1970's technology. The outdated equipment coupled with the rising maintenance cost associated with operating an aging airframe has exposed several critical vulnerabilities. As a result, the Air Force needs to consider developing the next generation of AWACS.

In this paper, I will examine how the geopolitical conditions and the vulnerabilities of the E-3 fleet are driving the need to develop the next generation of AWACS, and what that platform should be. Given the current fiscal constraints and other higher-priority procurement projects, both a short-term solution and a long-term solution will be provided to either continue to upgrade the existing E-3 fleet or develop the next-gen AWACS. Given the type of research question, I used the evaluation framework for this research to provide the Air Force a recommendation to either continue updating the current E-3 platform or opt to replace it. This research paper's outline will provide a brief background of the AWACS concept and its importance on the battlefield. It will then provide an overview of issues and vulnerabilities of the current E-3 fleet, explaining how the aging airframe and technology, coupled with efforts from other nations, have begun to highlight an issue for the Air Force. Several different platforms both currently in production and conception will be evaluated based on several criteria. These criteria examine the need to account for routine operational and maintenance cost of the platform, the amount of time necessary to train aircrew to operate the platform, and the capabilities that platform provides in comparison to the current E-3 platform. The evaluations of each replacement options will be assessed and a recommended course of action to take for the next generation AWACS.

BACKGROUND

In the mid-1940's, a joint venture was started between the United States Navy and Air Force to develop an airborne early warning system to complement land-based radar stations. The result of this venture was Lockheed's EC-121 Warning Star. Based on Lockheed L-1049 Super Constellation, the purpose of the aircraft is to extend and cover any radar coverage holes of the land-based radar. Declared operational in 1954, the EC-121 provided early warning coastal radar coverage off both coasts of the United States. It was during the Vietnam War when the EC-121 saw extensive use in combat operations. During the war, it provided early warning and limited intercept control for United States fighters against North Vietnamese MiG fighters. Its successful use in the Vietnam War prompted the Air Force to seek a replacement. In 1963, the announcement was made for a replacement to the EC-121 utilizing jet propulsion and the latest technological improvements in radar and computer technology. In 1967, Boeing's concept based on their successful commercial 707 airframes, was given the go-ahead to produce two aircraft to be designated as a test bed and by 1973 was ordered to begin full-scale development and trials of the E-3 with production soon to follow. Since then, employed with great success in operation Desert Storm and Desert Shield as it flew more than "400 missions and logged more than 5,000 hours of on-station time, providing radar surveillance and control from more than 120,00 coalition sorties."[2] In addition to that "E-3 controllers assisted in 38 of the 40 air-to-air kills recorded during the conflict."[3] It saw successful follow-on operations in Allied Force in Kosovo, Odyssey Dawn in Libya, Enduring Freedom in Afghanistan, Iraqi Freedom in Iraq, and Inherent Resolve in Syria.

The successful use of the AWACS system has been so effective that other countries have begun to develop their own with varying degrees of success. These states have witnessed the use of the AWACS in multiple operations and have seen the effectiveness of AWACS as a force multiplier, enhancing the SA for US commanders on the battlefield.[4] As such, these states have expended considerable efforts either procuring an AWACS platform or indigenously producing their own. Russia has built their design based on the IL-76 transport, designated the A-50. China has a similar design in the KJ-2000, as well as some indigenous projects such as the KJ-200 and KJ-500. Sweden developed their own for domestic and export use in the Saab S100B and the Saab 2000 Erieye. Israel also has developed their own in the EL/W-2085 and EL/W-2090. The two most notable designs are the Russian A-50 and the Chinese KJ-2000 in which its capabilities, design, and crew complement are laid out to match those on the current E-3.[5]

Like many of the airframes in the US Air Forces' inventory, the E-3 AWACS is an aging platform in need of replacement. The first E-3 was delivered to the US Air Force in 1977, had an expected lifespan of 20-25 years, with the upgrades it has received the expected lifespan has been extended to 2035.[6] Since its inception in 1977, the E-3 has gone through several block modification upgrades to improve and bolster the capabilities it provides to commanders. These upgrades include the Block 30/35 modification these improvements included a passive detection system (PDS), Joint Tactical Information Distribution System (JTIDS), Radar System Improvement Program (RSIP), and computer hardware to handle the new equipment. Since 2014, the E-3 fleet is slowly being upgraded to Block 40/45 configuration, the E-3G. In this most recent Block 40/45, an entire computer overhaul was included to bring the DOS 2.0 like operating system of E-3 B/C in the Block 30/35 to a Windows 95 like operating system in the Block 40/45. Also, the AWACS will be given an updated flight deck avionics cockpit that will provide pilots with an all-glass cockpit.

This upgrade provides E-3 with a commercial off-the-shelf computer (COTS) update replacing the Sentry's "antiquated computers with a Red Hat Linux-based system for the main flight computer, and Windows-based operator workstations."[7] The new operating computer system allows the Air Force to easily upgrade the E-3 as new technologies and capabilities are brought online. This Block 40/45 update took over a decade to develop and cost approximately $2.6 billion and would extend the service life of the E-3 to 2035. However, although declared a significant improvement over the older Block 30/35, it encountered a series of issues. After the initial acceptance by the Air Force, additional testing and evaluation report highlighted issues with the program.[8] The most notable of this issue was during a Cooperative Vulnerability and Penetration Assessment test assessing the cyber vulnerabilities of the E-3G and its ground support system exposed that the "E-3G version 3.0 and supporting Block 40/45 ground systems are highly vulnerable to cyber threats and not survivable."[9] Another issue is the age of the systems the E-3 utilizes. The Lexington Institute discusses how the airframe and the increased cost of maintaining these platforms have been a strain on the limited fiscal resources available in the current budget situations. According to an Air Force spokesperson, "the primary cause of errors is traceable to legacy analog sensors, which were not upgraded as part of the Block 40/45 modification."[10] The E-3 utilizes an AN/APY-1/2 Radar, which is the same sensor equipment that was originally retrofitted to the jet in its acceptance in 1977. As a result, with lack of a "near-peer" threat, Air Force leadership has lowered the priority of a future replacement for the AWACS fleet.

Evaluation Criteria

In order to evaluate whether or not the Air Force should seek to continue to upgrade the existing AWACS fleet or opt to replace it, several criteria needs are clarified and defined. The first criterion is the cost of routine operations. In most military organizations throughout the world, the fiscal cost of operating any military equipment will determine the feasibility of its acquisitions. If the fiscal cost of operating is not proportional to the operational advantages that the military receives, then it is unlikely that that organization would seek to procure the equipment despite what capabilities it offers. The second criterion is the cost of any potential upgrades to either the existing platform or a new platform. If the potential cost of upgrading the current system is not proportional to the capabilities it gains, then leadership might opt to cease upgrading the current platform and seek to obtain a new platform. This leads into the third criterion which is the costs of procuring a platform that is already in production or costs of the research and development needed to build an all-new platform. In this criterion, the costs in capabilities of a brand-new platform must be assessed against those that are already in production. If the benefits of developing a new system do not outweigh the costs involved, then it would make more fiscal sense to procure an existing system.

A final and most important criterion is the capabilities of the new platform. The platform must be able to be just as capable as the current system that it is replacing. If the system fails to provide the necessary capabilities to replace the current system, then it would be wiser for the Air Force to continue to upgrade the current system than to replace it. This is due to the enormous cost associated with the research and development of the new system and its eventual procurement. In this evaluation, this final criterion will be compared to the existing E-3 fleet. If the option to seek and develop a new platform and its associated fiscal cost does not give it the technological advancements that leadership seeks to obtain, then leadership would more than likely consider continuing to upgrade the existing E-3 fleet than opting to replace it.

Airborne Early Warning Platform Options

Prior to application to of the evaluation criteria, the next several pages will establish the different options that are available as a replacement to the E-3. The pages will include background information to include the general airframe specifications and capabilities, operational costs and any proposed future upgrades, and amount of time necessary to adequately train an aircrew to operate each system.

Boeing E-3 Sentry (AWACS)

Airframe and Capabilities

The E-3 is employed by NATO and the countries of United States (E-3B/C/G), United Kingdom (E-3D), France (E-3F), and Saudi Arabia (E-3A). All of these are based on a modified Boeing 707/320 commercial airframe with the added airframe modification of the rotating radar dome. The Air Force operates three different models of the E-3 Sentry with an additional airframe modification of the passive detection system (PDS) housed in fairings along the nose, cheeks, and tails of the aircraft. The E-3 aircrew consists of roughly 4 flight deck and 13-19 mission crew specialists, and with its four Pratt and Whitney TF33 turbofan engines and a fuel capacity of 21,000 gallons, it has a range of more than 5,000 nautical miles unrefueled. However due to the mission profile that the E-3 flies, its standard profile is approximately 8 hours duration without refueling.[11] With the added capability of aerial refueling and augmented flight crew, the E-3 can extend its flying duration to approximately 24 hours. The primary system on the E-3 is the AN/APY-1/2 radar system, a mechanically scanned system in horizontally and electronically scans vertically. It can provide a scan of over 200,000 square miles around the E-3 every 10 seconds. The primary operational mode is "pulse Doppler non-elevation scan (PDNES) for surveillance of airborne target; pulse Doppler elevation scan (PDES) to determine the target elevation; beyond the horizon pulse radar mode; receive only mode for passive operation; maritime mode which uses very short pulse width for the detection of surface ships; and standby mode."[12]

In 1987, the E-3 was upgraded to its current configuration, the Block 30/35 modification on its E-3B/C model. In this modification, the AN/APY-1/2 radar system went through a Radar System Improvement Program. This program was a joint venture between the United States and NATO. The RSIP improves the AN/APY-1/2 radar detection capability against targets with smaller radar cross section such as cruise missiles and low observable aircraft. The power for the radar is provided by electric generators mounted on each of the E-3s Pratt and Whitney's TF33 engines produced a combined output of approximately one megawatt of power. The E-3 also gained a passive electronic support measure system (ESMS) the AN/AYR-2 or also known as the passive detection system (PDS). The PDS system allows a specialist onboard the E-3 to "associate any electromagnetic emission to a specific threat system."[13] This system allows controllers onboard the E-3 to provide situational awareness of any possible threat surface-to-air missile systems or threat aircraft thus allowing friendly aircraft to determine strike routes and tactics to address those threats. Another key upgrade to the AWACS in this block upgrade is the installation of a Joint Tactical Distribution System (JTIDS) terminal. The installation of this terminal provides the E-3 a "jam-resistant digital communication of data and voice for command and control, navigation, relative positioning, and identification."[14] In 2003, the E-3 underwent a massive upgrade. The E-3G or Block 40/45 upgrade, is the first significant overhaul of the AWACS platform since its development in the late 1960s.[15] This upgrade replaces the 1970's based computer system with the latest commercial off the shelf computer systems in which according to Col David Gaedecke, a former commander of the 552nd Air Control Wing, would provide the AWACS community capabilities that are much more advanced the older model Block 30/35.[16]

Several additional modification programs are underway on the E-3. One of this modification is the Diminishing Manufacturing Sources Replacement of Avionics for Global Operations and Navigation or DRAGON. Ground tested in 2014 and fielded on only one Air Force aircraft so far, the purpose of the DRAGON modification is to remove and replace much of the analog equipment on the flight deck with more readily available commercial digital systems. This modification was necessary due to the inability to find replacement parts for many of the non-sustainable steam gauge systems. This modification included new digital glass displays, digital satellite-based communications, a modern flight management system, and a new Identification Friend or Foe (IFF) capability.[17] NATO is also pursuing the DRAGON modification with its first aircraft modified and delivered in November 2016.[18] Another program in the installation of the AN/UPX-40 Next Generation Identification Friend or Foe (NGIFF) system. All these systems allow the Air Force to downsize the flight crew from four to three, with the elimination of the navigator. Another upgrade is the Internet Protocol-Enabled Capability or IPEC. According to a report by the Congressional Research Service, IPEC would provide a permanent INMARSAT-based IP-enabled communications package.[19] This communication package would allow operators onboard the E-3 real-time access to the Department of Defense's classified network, SIPRNET.

Operational Costs

One of the issues with the existing E-3 fleet is that the Boeing ceased production of its 707/320 airframe in the early 1990's. As a result of this sustainable replacement parts for many of the aging components are becoming more and more difficult to procure. More often than not, many of these parts have to be custom made by the maintenance group's fabrication shops. In 1999 the estimated operational and maintenance (O&M) cost of E-3s was approximately $225 million[20] and climbed to approximately $327 million in 2012.[21] The issue with the lack of replacement parts and rising operational costs have even led NATO to retire the first of its 16 E-3A in 2015.[22] Although there are currently no plans to retire the remaining NATO E-3 fleet until 2035,[23] studies are underway to review options to modernize the fleet while reducing overall manpower and financial costs. One example of the rising costs is the issue of the E-3 fleet's TF-33 engines.

The rising cost of overhauling or replacing the TF-33 engine has risen in recent years due to the diminishing use it in the Air Force. The aircraft that are currently utilizing the TF-33 engines is limited to the B-52H bomber and the E-3 since the E-8C JSTARS was re-engine in

JT8D engines in 2005. However, with the Air Force looking to re-engine the B-52H. The acquisition of a new engine on the B-52H would leave the E-3 as the sole operators of the TF-33. It was estimated that the cost to overhaul or replace the engine has risen from an estimated $257,000 in 1996 to $1.25 million in 2006.[24] In 2004 Boeing proposed the option to re-engine the E-3 with CFM56-2 series engines along with the E-8. The CFM56-2 series engines are currently utilized on the KC-135 and RC-135 and are much more fuel efficient and have a reduced maintenance cost than the TF-33 while providing increased performance. The current TF-33 engines provide 21,000-lb-thrust of the TF33s, while the newer CFM engines provide 24,000-lb-thrust.[25] In 2006, Boeing and GE estimated that this cost would approximately $33 million per aircraft,[26] totaling roughly approximately $1.8 to $2.2 billion.[27] Despite its initial procurement cost, the re-engine program would have an additional cost-savings impact since it will utilize a standardize engine across several different Air Force platforms. Although this option is not being pursued by the Air Force and NATO, the other E-3 operators have.

Training

Due to the various specialists that the E-3 employs, training varies among the different crew position. The E-3 is separated into roughly two different groups, the *front end* and *back end*. The *front end* is the flight deck composed of four members, two pilots, a flight engineer, and the navigator. The *back end* is the mission crew, which can be further separated into two categories, the *scope operators* and *techs*. The *scope operators* are those that occupy the mission consoles and are comprised of Air Weapons Officers, Senior Director, Air Surveillance Officer, Electronic Combat Officer, and the Mission Crew Commander. The *techs* are the technicians maintain and troubleshoot the various systems are comprised of the Communications Systems Officer, Communication Technician, Computer Display Maintenance Technician, and Airborne

Radar Technician. Each of the specific training for each specialist after tech school varies by position.

Overall the qualification training ranges from four to seven months. The mission crew training is typically the longest with the Air Surveillance Officer syllabus that lasts approximately seven months. The length of this training is due to personnel learning and understanding how to utilize the existing Block 30/35 systems on the E-3B/C. The Block 40/45 with its windows interface is considered considerably easier to training. However, the 552nd Air Control Wing has yet to fully transfer all initial qualification training (IQT) for new personnel directly into the 40/45 systems. The current platform has each personnel going through the 30/35 system before going through a certification process on the 40/45 system. There are discussions to transfer all E-3 IQT to the Block 40/45 around July of 2018. However, the syllabus for the training has not been finalized.

Boeing E-767 Airborne Warning and Control System

Airframe and Capabilities

Developed in 1993, the E-767 has initially been a joint venture between the United States and Japan under an agreement between President George Bush and Japanese Prime Minister Kiichi Miyazawa. Based on the Boeing 767-200 airframe, the E-767 was built as a request to Japan's Air Self-Defense Force's requirement for an AEW platform to supplement's its E-2C Hawkeye. With the closing of the 707-airframe production line in 1991, the Air Force and Boeing undertook efforts to acquire a suitable alternative to the 707-airframe, the Japanese Defense Agency. As a result of this, Boeing proposed basing its E-3 aircraft system on a newer airframe based on the 767. This allows Boeing to utilize the E-3 radar system, which is the

AN/APY-1/2 currently employed on the E-3, without the extraneous developmental costs of developing a new airframe. Despite this savings, the overall program cost was estimated to be $2.3 billion with each E-767 unit costing approximately $300 million. There are four E-767 in existence today, all are in service with the Japanese Air Self-Defense Force (JASDF).

From an external point of view, the E-767 looks very similar to the E-3 with the exception that it is a 767-200ER airframe as opposed to a 707-airframe. It utilizes two General Electron CF6-80 turbofan engine providing 61,500-lb-thrust capable of 12-hours total flying time providing approximately.[28] Unlike the E-3, the E-767 is unable to extend its flying time and station duration since it is unable to aerial refuel. Overall the E-767 is six feet longer and has approximately twice the cabin volume. The increased size of the airframe and the newer engines allow the E-767 to fly higher, faster, and have a longer duration than the original E-3 airframe.[29] The aircrew consists of 2 flight deck and approximately 13-18 mission crew specialist. The overall system capabilities of the E-767 mirror those that currently available on the E-3 minus several vital systems to include the ESMS. The primary sensor, the AN/APY-1/2 radar system, onboard the E-767 is the same to include the RSIP upgrade which was completed in December of 2012. In a news release by the Defense Security Cooperation Agency, an additional upgrade the E-767was proposed in 2013. This upgrade, estimated to cost $950 million, included a mission computing upgrade, the addition of ESM systems, as well as the NGIFF system.[30] This update would bring the E-767 increased compatibility with the Air Force E-3s.

Operational Cost

With the Air Force in the process of procuring another Boeing 767 airframe, the KC-46, the potential cost would be reduced for procuring additional airframe to be modified with the AWACS. A report in 2014 estimated that the average cost per KC-46 would be approximately

$190 million[31] with another $125 million needed for airframe modification. The estimate is based on the fact that the Boeing 767 airframe production line is still operating, and it is much more cost effective modifying an existing airframe already in production. A Congressional report estimated that an additional $1.8 billion[32] would be necessary to provide the support operations for the new airframe. However, the most significant cost savings of the E-767 will be the daily operational and maintenance (O&M) costs. This savings is because the 767 airframe is widely used in the commercial world, the ability to acquire sustainable replacements parts would be much easier than the current E-3. Additionally, the 767 operates on two engines as opposed to the four currently used on the 707, thus would reduce the maintenance needed and costs associated with fuel savings. Final cost-saving measures come with the sensor system of the E-767. Since the E-767 sensors utilize the same AN/APY-1/2, ESM, and other systems that the E-3 employs, the maintenance and support infrastructure is already in place and would not require any further updates or modifications. The only concern is that Boeing might discontinue the 767-production line since it introduced the 787 Dreamliner as its replacement. However, with Boeing awarded the KC-46 contract, the 767-production line has been extended.[33]

Training

Initial Qualification training for the E-767 for the Air Force would be similar, if not exactly the same, as the current E-3 platform. This training is mainly because all the systems on the E-767 are exactly the same as the E-3. There will have to be some modifications. The existing flight deck aircrew on the E-3 consists of four individuals, two pilots, a navigator, and a flight engineer. The E-767's flight deck, however, only consists of the two pilots. The elimination of the navigator and flight engineer would require some additional syllabus training for the pilots as they learn about the capabilities and restrictions of the 767 airframes. The remainder of the mission crew to include the scope operators and techs training will be similar to the E-3. The computer system that the JASDF aircrew trains to is the Lockheed Martin CC-2E. Although the CC-2E system has a larger capacity than those installed on the Air Force E-3 aircraft, its operating system layout is the same.[34]

Boeing E-737 Airborne Early Warning and Control

Airframe and Capabilities

The Boeing 737 AEW&C or E-7A Wedgetail as designated by the Royal Australian Air Force (RAAF) was developed at the request of the Australian military in 1996. The E-737, based on the Boeing 737-700 aircraft, utilizes two CFM56 engines. These engines are similar to those that on the KC-135 and RC-135, allowing the E-737 to operate between altitudes of 30,000ft-40,000 and has a flight time of 11 hours with an approximate station time of 9 hours.[35] The station time is extendable since the E-737 is capable of aerial refueling thus limiting the aircraft's flight duration to aircrew flight duty day restrictions. Due to its smaller size, the aircrew of the E-737 consists of two flight crew and six to ten mission crew.[36] First delivered to the RAAF in 2009, it has been utilized in operations in Iraq and Syria against the Islamic State of Iraq and the Levant (ISIL).[37] There are fourteen E-737 in operations today with the Royal Australian Air Force, Turkish Air Force, and Republic of Korean Air Force. It is equipped with a Northrop Grumman Electronic Systems Multi-role Electronically Scanned Array (MESA) radar. Capable of scanning electronically in both azimuth and elevation, the MESA radar is capable of providing 360-degree coverage at a range of more than 200nm simultaneously.[38] MESA provides the RAAF aircrews ability to continuously scan an area and track both airborne and maritime targets without experiencing the six-second delay that is associated with the E-3's mechanically azimuth scanned AN/APY-1/2 radar.[39] This MESA radar which mounted in a dorsal fin configuration, or "top hat," is designed to have minimal impact to aircraft performance characteristics while maintaining the required 360-degree coverage.[40]

In addition to the radar, an electronic countermeasures suite is also fitted to the E-737. Israeli industries Elta Electronics ESM system supplied an advanced ESM/ELINT ESM system, similar to those RAAF P-3C Orion maritime patrol aircraft.[41] This system allows the E-737 to have a limited ELINT capability similar to the E-3 PDS. This capability allows RAAF aircrew to passive detect electromagnet emissions and uses those emissions to help identify airborne targets. Other electronic countermeasure systems come in the form of the AN/AAQ-24 (V) Nemesis directional infra-red countermeasures (DIRCM) system, augmented with the Viper solid state multiband laser developed by Northrop Grumman. Currently fielded on Air Force AC-130/MC-130 aircraft, the DIRCM is designed to defend the E-737 against all field IR missile threats.[42]

Operational Costs

In a 2004 report by the Australian government Boeing estimated that to operate and maintain the E-737 it would cost the RAAF approximately $90 million Australian dollars or $71 million US dollars.[43] Given the smaller size and smaller associated support infrastructure, this could drive down the operational costs of the E-737 even further. With 8,000 aircraft delivered and another 4,000 on order for both commercial and military operators, its extensive proliferation among both sectors allows the Air Force to obtain replacement parts for the 737 airframes easily. Another operational cost would come in the CFM56 engines. Downsizing from four to two and more fuel-efficient engines would save the Air Force nearly a hundred million gallons of jet fuel per year.[44] Another operational cost would come from the central MESA radar and computer systems onboard the E-737. Since the MESA radar is both electronically scanned in azimuth and elevation, it lacks the mechanically rotary spinning drive that is prevalent on both the E-3 and E-767. This cost savings measure reduces necessary maintenance times to preserve the system. The other is the computer system. This computer support system is designed to be an open-architecture, similar to what exists on the E-3G. This system would make any replacement more attainable since it is comprised of mostly COTS components. The Air Force could potentially save about $100 billion over the life-span of the E-737 with annual savings exceeding $3 billion.[45] One of the major issues is that with the lack of technicians onboard the E-737, onboard troubleshooting will prove to be difficult. The limited amount that could be done in the air will force any issues and malfunctions that could not be solved in the air be done with maintenance on the ground.

Training

The Air Force would be required to alter the initial qualification training for its aircrew to support the E-737. Although many of the core competencies for personnel transiting to the E-3, specific airframe difference training will be required. Like the E-767, the E-737 only utilizes two pilots for its flight deck crew. As such like the E-767, the elimination of the navigator and flight engineer positions would require additional training for the pilots. Since pilots have already received the fundamentals of these positions during their initial undergraduate pilot training, all that would be required for those qualifying on the E-737 is a refresher and difference training associated with the platform. The same could be same for the mission crew. Since the computer system are comprised of COTS system, its similarity to the E-3G computer systems affords a much more natural transition from the E-3 to the E-737. The lack of any technicians, however, on board would require some additional training to accomplish the limited amount of system troubleshooting in flight.

Brand-New AWACS Conceptual Platform

Although many studies theorize what the next generations of AWACS platform should like, no one has offered any official research and proposals since the E-10 Multi-sensor Command and Control Aircraft or MC2A. The E-10 was initially developed in 2003, as a potential replacement to all Air Force Boeing 707 airframe based Intelligence, Surveillance, and Reconnaissance (ISR) aircraft. These aircraft included the E-3 Sentry, E-8 JSTARS, and the RC-135 Rivet Joint. Boeing initially proposed it to be based on the 767-400ER airframe. The intent behind this was to merge and integrate command and control, intelligence, surveillance, and reconnaissance (C2ISR) functions into a single platform.[46] The capabilities of the E-10 would be increased in increments or "spirals." The first increment would be the equipping of the Northrop Grumman/Raytheon Multi-Platform Radar Technology Insertion Program (MP-RTIP) radar and an advanced Battle Management Command and Control system.[47] The MP-RTIP was designed to provide advanced ground-moving-target indicator (GMTI) capability similar to that of the JSTARS while also providing a focused Air Moving Target Indicator (AMTI) capability. AMTI capability would allow the E-10 to be much more effective in Cruise Missile Defense (CMD) operations that the E-3 and its AN/APY-1/2 radar has been proven difficult to accomplish.

The second spiral was intended to use a variant of this radar system and designed to merge the capabilities of the AWACS radar and the JSTARS into a single system capable of tracking both airborne and land/surface based targets. However, an Air International article published in August 2003 suggested that the development of a single airframe utilizing two separate radar systems for airborne search and ground search had to be abandoned.[48] The proposed MP-RTIP radar was causing electronic interference with the MESA radar, and the 767 airframe was unable to fulfill the required power requirements necessary to operate both radars simultaneously.[49] As a result of this, the Air Force dropped its requirement for MESA, limiting the E-10 to the JSTARS role. This program would eventually be canceled by the Air Force in 2006. The final decision to cancel the E-10 was based on two factors. The first was the rising developmental development cost of the program which was estimated to be about $7.3 billion through 2013.[50] The second was the with the DoD cutting its budget throughout the development; the Air Force sought ways to reduce its overall budget while maintaining fiscal resources to fund other programs. The concept of a brand-new airframe could potentially provide the Air Force the capabilities of both the AWACS and JSTARS into a single platform. The ability to merge the two systems into a single airframe will save the Air Force a considerable amount in operational costs throughout its lifespan. The issue that plagues this program is the extensive research and development costs associated to produce and procure this airframe as evident by the E-10 MC2A project.

One potential theory was to mount a MESA-like system on an unmanned aerial vehicle (UAV), like the RQ-4 Global Hawk. By placing this system on a UAV, it would reduce the need for a large aircrew and support infrastructure. This reduced footprint would allow an AWACS system the flexibility to operate out of more airfields that would have been otherwise limited due to the required runway length/strength and support infrastructure that the E-3 needs. The smaller size of the UAV would eliminate many of the necessary infrastructures that are normally associated with large manned assets. Finally, the long endurance of the UAV would provide a longer consistent C2ISR coverage due to the existing aircrew duty day limitations that are associated with a manned aircraft. Although not as cost-effective in comparison to the other UAVs in the Air Force's inventory, its operational and maintenance costs are comparable to the

E-3 at approximately $15.5 million per aircraft.[51] There, however, were several drawbacks with replacing the E-3 with a UAV.

The first was the power requirement for the radar. Due to the limited output that could be provided by the single-engine UAV, the radar that could be equipped on the UAV would have a limited range. This would require an increased number of UAVs required to provide the same area coverage as a single E-3. Also, the lack of power would prevent the radar to *burn* through any potential enemy electronic countermeasures (ECM). Another weakness is that UAVs need a satellite communications link for both control and link transmission of the radar feed both of which makes it vulnerable to jamming.[52],[53] Another drawback is the inability to provide real-time command and control to airborne assets. The weight and space constraints of the smaller platform do not allow the UAV to obtain the communications suite capabilities that would facilitate this ability.[54] As a result, under this concept battle management command and control would have to be moved to a Ground Theater Air Control System (GTACS). Although GTACS are capable of providing the C2 function, its reliance on satellite links for its radar pictures and the control of the UAV is vulnerable to jamming as well. Additionally, due to line sight of issues with ground-based radios, GTACS are unable to provide the same communications coverage compared to the E-3 unless more radios in multiple locations are acquired. In a predominantly land-based operational area, the multiple located radio requirements would not be an issue. However, if the operational area is predominantly ocean-based, then it would this requirement difficult as there are limited areas to station radios to provide radio coverage.

One potential proposal, designated the AWACS Bistatic UAV Adjunct, was stated to have a prototype developed by 2008.[55] With an acquisition budget of $850 million, this program was not intended to replace the AWACS but to help supplement it with UAV coverage. Its basis of the proposal was to have the E-3 act as the radar transmitter while a High Altitude Long Endurance (HALE) would be the receiver.[56] This would allow the E-3 to the act as the central node while allowing the UAVs to extend the radar coverage while reducing the number of AWACS need to provide the same amount of coverage. However, the same issues in a full E-3 UAV replacement would apply in this case. The vulnerabilities and weakness associated with the UAV satellite link for radar picture and control will affect this concept as well.

A final option is to have the whole mission be replaced by a satellite-based system. By placing an AWACS radar system in space, it would provide leadership a near constant 24/7 coverage of a selected area of interest. There are several issues with this such as of 2006 there is no air-moving target indicator (AMTI) necessary to detect airborne targets.[57] The existing space-based radar systems are limited to Synthetic Aperture Radar (SAR) imagery and ground-moving target indicator (GMTI), the same capabilities of the E-8. One of the issues that there is no AMTI capability in space is that existing Doppler radar techniques needed to detect airborne targets are difficult to achieve due to the limited revisit rate of current radar, power consumption, and expansive distance of which the satellite-based radar transmits the signal.[58] Another issue is the limited communications that can be utilized. The satellite link that is necessary for the satellite to send its radar pictures to those that need it is easily jammed. The satellite link also ties into the radio communications as few of Air Force aircraft has the ability of satellite communications (SATCOM). Also like the UAV, the inherent delay with SATCOM communications would make tactical C2 control of airborne assets nearly impossible. These issues would have to force the battle management to be placed at a GTACS site which is vulnerable to cyber-attack and satellite communications jamming. A final issue is the cost necessary to employ such a system. It is estimated in 2000 that the employment of such a system would cost approximately nine billion dollars.[59] The substantial procurement cost and those associated necessary to operate and maintain a space-based platform would make any potential upgrades costly.

Analysis of the Evaluation Criteria

Based on the evaluation of the different options that are available to the Air Force for the next generation AWACS, this paper will present a short-term solution or a long-term solution. These solutions will take into account the fiscal constraints of the Air Force budget, the urgency to replace the AWACs, and the capabilities it provides to the Air Force in comparison to the E-3. The best immediate short-term solution to the AWACS replacement would be the continual upgrade of the E-3 to include the new CFM-56 engines. The new fuel-efficient CFM-56 engines and its widespread use in both the military and commercial sectors will help provide the Air Force a cost-reducing option with a longer-sustainable logistics supply line. Additionally, the operational research and development for the E-3 are already fully funded, and the upgrades already in place are projected to extend the service to 2035 and perhaps beyond. The inclusion of the DRAGON modification reduces the flight crew from four to three, saving the Air Force the resources required to maintain that position on the aircraft. Finally, with the Block 40/45 upgrade to its computer systems, makes the E-3 airframe easier to upgrade and maintain due to its commercial off the shelf open-architecture computers. In a fiscally constrained environment of Air Force budget, this option is the more practical solution in the short-term, since it does not necessitate the need to procure AEW platforms already in production. Additionally, this solution will give the Air Force more time to allow technological development to advance to provide the Air Force a better solution.

The best long-term solution to this is the E-767. The E-767 provides a brand-new airframe that is not only much more fuel-efficient than the E-3 but also has double the cabin volume. This cabin space will allow the Air Force not only to upgrade the systems onboard the aircraft but also to allow room to provide additional capabilities that are not available on the existing AWACS system. Additionally, with the Air Force procuring the KC-46 tanker based on the 767 airframes, it would provide a standard airframe between the E-767 and the KC-46. This would give the Air Force easier access to the supply chain for the E-767 since it is acquiring replacement parts for an airframe that is used in the commercial sector. Another cost saving issue is that modern cockpit that is onboard the E-767, it further reduces the flight deck crew from four to two. The reduction would in turn reduce flight crew training costs. Additionally, with the sensors employed on the aircraft, training can be easily transferred from the E-3 to the E-767, with only flight deck requiring a difference training. The similar systems will also allow the support infrastructure in place to support the E-3 also to support the E-767. This is a cost-saving measure as operational and maintenance costs for the onboard systems can be directly transferred to the new airframe. The only issue with the E-767 as it is designed right now, the aircraft is incapable to be refueled in flight. The airframe would have to be modified to make it aerial refueling possible. This modification is under contract to be incorporated into the Boeing KC-46 Pegasus tanker.[60] With the KC-46 program in place, the Air Force can save additional resources since it only has to fund the airframe modification to support the AWACS sensors and systems.

The E-737 and the other conceptual AWACS platform would not be a good candidate to solve either solution. The E-737 is an acceptable solution. However, the capabilities that it provides does not match that of the current E-3. Although the E-737 does have an electronically scanned radar that could provide a faster refresh rate than the radar on the E-3, the lack of systems technicians onboard would make it difficult for aircrew to troubleshoot any potential issues with the onboard systems. This inability would force the E-737 to rely on troubleshooting on the ground thus limiting mission effectiveness if issues occur. Additionally, if the Air Force is to expend the fiscal resources to procure a new platform, the E-767 is a better candidate overall than the E-737. The smaller airframe of the 737 limits the space available to make any airframe modification to support any potential future upgrades. Finally given the current fiscal constraints and technological limitations, the Air Force does not have to expend the resources to support the research and development of an entirely new platform like those described earlier.

Recommendations

Over the last few decades, the Air Force has given top priority to acquire fifth generation fighter with enhanced sensor suites and network integration. This capability utilizes the multiple sensors organically on the aircraft and off to provide the pilot heightened situational awareness in the battlespace.[61] Skeptics of an AWACS replacement theorize that a fleet of fully networked integrated fifth-generation fighters would eliminate the need for the AWACS and other ISR platforms.[62] The *legacy* system of the AWACS would be forced further back from enemy lines due to new advanced SAMS such as the Russian S-300V4 and S-400 and an advanced integrated air defense (IADS) that are designed to destroy AWACS aircraft at a range up to 400km.[63] The issue is that with all the information flowing into the cockpit it can quickly overwhelm the pilot.[64] Additionally, although this information could provide increased tactical awareness of the battlespace, it does not provide the other battle management functions that could be required on the battlespace. In a current network structure, the fifth-generation fighters of the F-22 and F-35 can operate as a mini-AWACS providing battle management to other fourth-generation assets.[65] However, this is limited to tactical engagements in strike operations. The technology and network integration of the sensors and information do not afford the pilot the time or mental capacity to address any other potential issue.

The presence of an AWACS and its C2 functions can not only assist the F-22/F-35 in their strike operations and tactical engagements; it can simultaneously coordinate and support any time-sensitive target (TST) operations, real-time tanker fuel management, close air support (CAS) operations, and any potential combat search-and-rescue (CSAR) operations. This is demonstrated in operations occurring in the Middle East. In a highly permissive environment, the AWACS allow commanders to quickly and efficiently de-conflict highly congested airspace. These airspaces contain a large number of different aircraft that are all operating at different frequencies and taskings and are mostly unaware of each other. These aircraft are also communications with ground forces that due to radio limitations on many of the manned assets are unable to communicate with.[66] The AWACS, with its large aircrew, can facilitate and manage these complex operations, whereas a single pilot in an F-22/F-35 is unable to do.

As a result, given the various options of AEW platforms and both a short-term and long-term solution presented in the paper, I recommend that the Air Force procure the E-767. The E-767 provides the capabilities that are currently present on the E-3 with the ability to easily upgrade its systems to support any future technological advancement based on its computer architecture and relatively *young* age of the platform. By placing the airframe on a successful popular commercial airframe, it affords the Air Force the ability to rapidly procure replacement parts as opposed to manufacturing hard to source out of production parts on the existing E-3. The similarity of the sensors systems on board the E-767 compared to the E-3 makes it easier to replace and rapidly integrate the new platform into the Air Force with little to no modification in training or operational practices. Finally, the research and development needed for the E-767 have already been funded. This would eliminate the need to source additional funds to develop a replacement with desired capabilities that existing technology cannot support.

Conclusions

In the last several conflicts that the United States Air Force has participated in, there has been a lack of credible threat that would challenge its C2 structure. As a result, Air Force leadership has not deemed the next-generation AWACS as a high-priority issue. In recent years, near-peer adversary such as China and Russia has seen the importance of this type of assets and has made considerable efforts to develop their own while simultaneously developing technology to defeat ours. Several different AEW options are available to the Air Force. These options are those that have already been developed and in production and other options are conceptual ones that have been theorized. Although fifth-generation fighters such as the F-22 Raptor and the F-35 Lightning II and its enhanced sensors, can be a mini-AWACS, these fighters lack the ability to provide the level of battle management that the E-3 provides. The ability to transfer that capabilities to GTACS are feasible. However, with the reliance on dis-located ground radar and radio sites, the link connections are susceptible to jamming. If jammed effectively it could separate the tactical operators from the battle management leadership on the ground. It is this crucial role that the AWACS plays that necessitates the need to develop the next-generation replacement.

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