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U.S. Electronic Attack Aircraft

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Summary

Electronic warfare (EW) has been an important component of military air operations since the earliest days of radar. The advent of the airplane enabled the United States to project power faster than land and naval forces had ever done. It also spurred the development of technologies, such as radar, that could detect and track enemy aircraft, thereby protecting military forces, infrastructure, and populations from aerial threats.

Department of Defense EW Activities

The Department of Defense (DOD) is engaged in numerous developmental EW activities. These activities include research and development (R&D) programs, procurement programs, training, and experimentation. Such activities are designed to improve various electronic attack (EA), electronic countermeasures (ECM), and suppression of enemy air defenses (SEAD) capabilities both in the near and long term. DOD EW activities often cut across service and intra-service community boundaries and defy easy categorization and oversight, making it difficult to determine and assess DOD-wide EW priorities. Although DOD does not have an overall EW procurement strategy, it is focusing more on this aspect of military operations in response to emerging threats.

The DOD budget request for FY2017 showed an increase in Research, Development, Testing and Evaluation (RDT&E) funds for EW. Congressional appropriations and authorization conferees often matched or exceeded DOD's request for EW programs to help ensure the survivability of numerous aircraft and to increase the military's ability to suppress or destroy enemy air defenses.

Congressional Decisions Regarding EW

Congress has the authority to approve, reject, or modify Air Force and Navy funding requests for EW aircraft sustainment and modernization. Congress also has the authority to provide oversight of the nation's EW requirements and capabilities. Congress's decisions on appropriations for the airborne EW aircraft fleet may affect the United States' EW capabilities, as well as the U.S. defense industry.

As part of its FY2017 budget authorization, appropriations, and oversight responsibilities, Congress may influence DOD's EW force structure, aircraft survivability, and air campaign effectiveness. Potential congressional oversight, authorization, and appropriations concerns for the sustainment and modernization of DOD's airborne EW force include the following:

- a potential shortfall in EW capabilities if funds are not available for sustainment and upgrades that would keep the weapon systems viable until they are replaced;
- ascertaining DOD, Air Force, and Navy priorities for sustainment and modernization; and
- potential implications that changing the number of EW aircraft may have on future rounds of base realignment and closure efforts.

Report Focus

This report focuses on the definition of EW and the four primary aircraft that are the main assets for this mission area:

- the Navy's EA-18G,
- the Marine Corps' EA-6B Prowler,
- the Air Force's EC-130H Compass Call, and

- the F-16CM Block 50 "Wild Weasel."

The report also addresses potential congressional oversight and appropriations concerns for the sustainment and modernization of the DOD's EW aircraft. It does not address options for recapitalization currently being offered by industry.

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Introduction[1]

Since the advent of the airplane, air superiority has been a critical component of military success. Electronic warfare (EW) plays a critical role in strengthening and securing the United States' air superiority. For the past 25-plus years of military operations, the United States has maintained a proficiency in airborne EW unrivaled by its near-peer adversaries. In recent years, however, such adversaries have invested in new technologies to advance their EW capabilities, thereby narrowing the EW capability gap. As a result, the U.S. military may not be able to achieve air superiority against a near-peer adversary, such as Russia or China, as easily as it has in the past. The United States may have to fight its way in the increasingly difficult anti-access/area-denial (A2/AD)[2] environment posed by advanced military forces.

The Department of Defense's (DOD's) electronic attack aircraft capabilities help ensure that the United States keeps an effective military and a technological fighting edge in the EW arena, accomplishing national goals while minimizing risk to U.S. forces. DOD's primary U.S. electronic attack aircraft are (1) the Navy's EA-18G, (2) the Marine Corps' EA-6B Prowler, (3) the Air Force's EC-130H Compass Call, and (4) the F-16CM Block 50 "Wild Weasel."[3]

This report addresses potential congressional oversight and appropriations concerns for DOD's airborne EW aircraft fleet. Congress has the authority to approve, reject, or modify Air Force and Navy funding requests for EW aircraft sustainment, modernization, and recapitalization, as well as to maintain oversight of the nation's EW requirements and capabilities. Congress's decisions on appropriations for the EW force could affect the nation's EW capabilities and have an additional impact on U.S. armed forces' ability to operate in a contested environment.

Electronic Warfare Definition

DOD defines electronic warfare as "any military action involving the use of electromagnetic and directed energy to control the electromagnetic spectrum or to attack the enemy ... the three major subdivisions within electronic warfare are: electronic attack, electronic protection, and electronic warfare support."[4]

Electronic attack activities include jamming or deceiving an enemy's radar or radio communications, oftentimes by exploiting information collected by electronic warfare support assets.

Electronic protection (or electronic countermeasures [ECM]) also jams or deceives an adversary's use of the electromagnetic spectrum. ECM is usually used in the "end game," for example, when an enemy missile has locked onto an aircraft and is homing in for a kill.

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[1] This section draws upon of the work by the late CRS analyst (name redacted) in his CRS Report RL30841, *Airborne Electronic Warfare: Issues for the 107th Congress*.

[2] *Anti-access* is defined as actions and capabilities, usually long-range, designed to prevent an opposing force from entering an operational area. *Area-denial* refers to actions and capabilities that generally have shorter range and limit an opposing force's freedom of action within an operational area

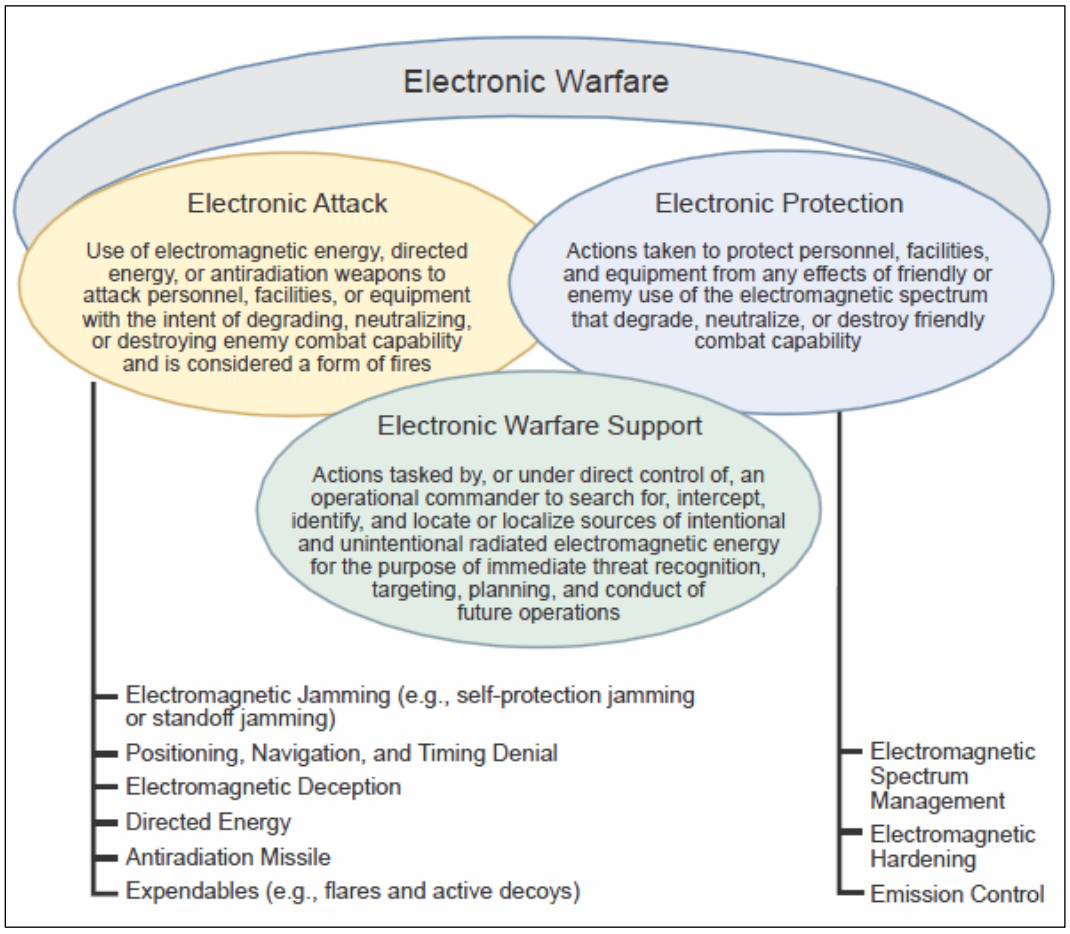
[3] See http://www.afhra.af.mil/factsheets/factsheet.asp?id=9738. Note the term "Wild Weasel" is given to the mission and various aircraft that have performed the Suppression of Enemy Air Defenses (SEAD) mission over the years, beginning with the F-100, F-105, F-4, and now F-16 Block 50.

[4] Department of Defense, Joint Publication 1-02 DoD Dictionary of Military and Associated Terms, at http://www.dtic.mil/doctrine/new_pubs/jp1_02.pdf, p. 76.

Electronic warfare support is, to the military, the foundation of EW. This activity includes "listening" to an enemy's radars and communications to determine what electromagnetic frequencies and wavelengths the enemy is using, so that others can better attack or protect against them.

The suppression of enemy air defenses (SEAD), while not a subset of EW per se, is an important mission area that exploits EW techniques, technologies, and platforms. DOD defines SEAD as "that activity which neutralizes, destroys, or temporarily degrades surface-based enemy air defenses by destructive and/or disruptive means."[5] In addition to exploiting EW techniques, SEAD platforms use bombs and missiles to attack enemy air defenses.

Figure 1. Overview of Electronic Warfare



Source: Department of Defense, Joint Electronic Library, Joint Publication 3-13.1 Electronic Warfare, at http://www.airpower.maxwell.af.mil/digital/Doctrine/du_jp3_13_1.pdf.

[5] Ibid.

The three EW subdivisions and SEAD are mutually supporting (see **Figure 1**). For example, all four of the U.S. electronic attack aircraft mentioned above perform the SEAD mission. The U.S. military's active radar jamming aircraft—the EA-18G Growler and EA-6B Prowler—employ EW self-protection systems. The Growler and Prowler both contribute to SEAD by jamming radar signals and firing High Speed Anti-Radiation (HARM) missiles to negate Surface-to-Air Missiles (SAM).

HARM Missile[6]

The AGM-88 High-Speed Anti-radiation Missile (HARM) is an air-to-surface tactical missile designed to seek out and destroy enemy radar-equipped air defense systems. AGM-88 can detect, attack and destroy a target with minimum aircrew input. The proportional guidance system that homes in on enemy radar emissions has a fixed antenna and seeker head in the missile's nose. A smokeless, solid-propellant, dual-thrust rocket motor propels the missile.

The F-16CM, like the Growler, fires HARM missiles. The F-16CM, along with the EA-18G, is DOD's primary anti-SAM aircraft, while the EA-6B and the EC-130H play critical roles in electronic support. All four EW aircraft use advanced ECM assets to protect themselves from attack.

Electronic Warfare Background[7]

Electronic warfare has been an important component of military air operations since the earliest days of radar. Radar, EW, and stealth techniques have evolved over time as engineers, scientists, and tacticians have worked to create the most survivable and effective air forces possible.[8]

During World War II, for instance, ground-based early warning radars were used during conflicts to detect attacking aircraft at long ranges, to direct fighters to intercept them, and to warn anti-aircraft artillery (AAA) batteries of imminent attack. These ground-based radars significantly improved the success of air defenses. The attrition of attacking aircraft rose accordingly. To negate or degrade ground-based radars, the Allies and Germany quickly developed a number of countermeasures, some of which are still employed today. Chaff (strips of metal that reflect radar emissions) was developed and used by both the Allies and Germany to confuse or obscure early warning radars. The Allies also developed radar-jamming and modified their aerial tactics to reduce the amount of time that aircraft spent in enemy radar coverage.

Just as countermeasures were developed to combat radar, countermeasures were developed to counter the anti-radar countermeasures. For example, Germany began using radar frequencies that were unaffected by Allied chaff. Germany also developed new techniques, such as intercepting aircraft radar navigation transmissions and identifying aircraft by the unique radar return generated by the aircraft's propeller.

In the post-World War II period, much research focused on using radar to guide surface-to-air missiles (SAMs) and AAA. Rather than simply warning the missile or artillery battery of the attacking aircraft's approach, radar now provided precise information to guide the missile or artillery shell to its target. In response to radar-guided SAMs, the United States sought to increase aircraft survivability in a number of ways. Some aircraft, such as the U-2, flew very high. Others,

[6] U.S. Navy official website, AGM-88 HARM Missile Fact File, http://www.navy.mil/navydata/fact_display.asp?cid=2200&tid=300&ct=2.

[7] This section draws upon of the work by the late CRS analyst (name redacted) in his CRS Report RL30841, *Airborne Electronic Warfare: Issues for the 107th Congress*.

[8] Bernard Brodie and Fawn McKay Brodie, *From Crossbow to H-Bomb* (Bloomington, IN: Indiana University Press, 1973).

such as the SR-71, flew very high and very fast. Still others, such as the F-111, flew very fast and at low altitudes. Many also carried electronic countermeasures.

The effectiveness of radar-controlled air defenses grew as they became more redundant and better integrated. For example, during the Vietnam War, the United States developed many techniques to enhance aircraft survivability against North Vietnam's quadruple-layered, integrated air defenses (e.g., the F-105 "Wild Weasel" SEAD aircraft, anti-radiation missiles, and airborne-jamming platforms, such as the EA-6B Prowler and EF-111 Raven).

The Wild Weasel[9]

By the time of the Vietnam War, countermeasures to aerial warfare had become considerably more sophisticated owing to improved radar systems and more effective surface-to-air missiles (SAMs). This was tragically apparent on July 24, 1965, when a U.S. Air Force F-4 was shot down by the North Vietnamese Army with a Soviet-made SAM. In response, the Air Force developed the Wild Weasels program. Each Wild Weasel fighter jet contained a pilot and an Electronic Warfare Officer, and relied on experimental equipment and tactics. Aiming to provoke enemy radar in order to precisely locate and destroy SAM nests, their missions proved to be the most dangerous of the war, as many Weasels were killed or captured.

The growing reach of SAMs and improvements to ground-based radars spurred new approaches to improving aircraft survivability. By using new materials and designs to reduce heat emanations and to deflect or absorb radar signals, aircraft such as the F-117 Night Hawk significantly reduced the probability of detection and tracking by adversaries. However, potential adversaries continue to respond to U.S. advancements by pursuing counters to "stealth" technologies. The downing of an F-117 Night Hawk—previously thought near invisible to radar—in the 1999 conflict in Yugoslavia (Operation Allied Force) by a Serbian SAM illustrates that control of the electromagnetic spectrum is an ongoing endeavor for U.S. air forces.

With exception of that incident, the United States has demonstrated a massive advantage over enemy-integrated air defense systems (IADS) for the past 25 years.[10] This advantage is apparent in the shrinking attrition rates of combat aircraft during the past several major air campaigns—from the Gulf War in 1991 to operations over the former Yugoslavia in the 1990s, the Iraq war in 2003, NATO air operations over Libya in 2011,[11] and the current fight against ISIS.

In terms of airborne electronic attack (AEA), the United States has dominated the electromagnetic competition against enemy IADS since the end of the Cold War. During this period, the U.S. approach to the AEA mission has focused on operating at stand-off ranges (beyond the engagement range of threat radars) and using EF-111s, EA-6Bs, and EA-18Gs to jam enemy early warning, acquisition, and tracking radars. In addition, the United States has used EA-6Bs, EA-18Gs, and EC-130H aircraft to jam the command and control (C2) datalinks that enabled the air defense network to coordinate and cue its various radars.

As countries modernize their IADS components, the United States and its allies are entering an era in which stand-off AEA alone may no longer be adequate.[12] Further, with the EF-111 having been retired in 1998 and the EA-6Bs scheduled to retire in 2019, the future of U.S. EW remains uncertain.

[9] Description of the book by Dave Pugl. 2015. "The Hunter Killers: The Extraordinary Story of the First Wild Weasels, the Band of Maverick Aviators Who Flew the Most Dangerous Missions of the Vietnam War." Library Journal 140, no. 8: 89. Academic Search Premier, EBSCOhost (accessed May 13, 2016).

[10] John Knowles, "Mission Profile: AEA for A2AD," *Journal Of Electronic Defense* 38, no. 11: 26-36 (2015).

[11] Ibid.

[12] Ibid.

Four Types of U.S. Electronic Attack Aircraft

All EW aircraft exploit information about enemy electronic activity collected by their own sensors or other electronic warfare support platforms. Moreover, all EW aircraft depend on electronic warfare support information to perform effectively. Although other manned and unmanned aircraft perform EW roles, this report describes DOD's electronic attack and SEAD aircraft (namely the Navy's EA-18G, Marine Corps' EA-6B, and Air Force's EC-130H and F-16CM Block 50), focusing on their capabilities and current sustainment and modernization efforts.

Boeing EA-18G Growler[13]

Figure 2. EA-18G Growler

Source: U.S. Naval Air Systems Command EA-18G website.

Note: See http://www.navair.navy.mil/index.cfm?fuseaction=home.display&key=33BFA969-0482-42CF-9E1F-F80A1B32BEE9

The Boeing EA-18G Growler, a two-seat variant of the carrier-capable F/A-18F Super Hornet Block II, provides the main airborne EA and SEAD capability for the Navy. The EA-18G combines the capability of the Super Hornet with the latest AEA avionics suite evolved from the Improved Capability III (ICAP III) system of the EA-6B Prowler.[14] The EA-18G's vast array of

[13] This section is broadly based on IHS Jane's, "C4ISR & Mission Systems: Air, Boeing EA-18G Growler," posted September 19, 2015.

[14] Ibid.

sensors and weapons provides a lethal and survivable weapon system to counter current and emerging threats.[15] Its primary mission is to detect and jam enemy radars.

There are currently 15 EA-18G Growler squadrons in the U.S. Navy. Except for one squadron (VAQ-141) at Naval Air Facility Atsugi, Japan, all are currently assigned to NAS Whidbey Island, Washington. Of the Whidbey Island Squadrons, one is a Reserve unit (VAQ-209) and another is the non-deploying training unit (VAQ-129). The squadrons traditionally deploy as part of carrier air wings aboard the Navy's 10 aircraft carriers; however, in a role typically played by the U.S. Marine Corps' (USMC's) squadrons, they can also deploy as land-based assets.[16]

Technical Data: EA-18G Block 1

The first variant of the EA-18G Growler is called the Block 1.These Growlers were test aircraft; there are no Block 1 Growlers in the inventory.

> The Block 1 Growler is equipped with up to three AN/ALQ-99 radar jamming pods, together with an AN/ALQ-218(V)2 receiver and a Raytheon AN/ALQ-227 communications countermeasures system, both of which are mounted on what would be the gun bay of the F/A-18E/F Super Hornet. The AN/ALQ-99 receivers are installed in the tail of the aircraft and the AN/ALQ-99 pod houses the exciters and the high radiated power jamming transmitters.[17]

Technical Data: EA-18G Block 2

The primary variant of the Growler, which entered fleet service in 2010, is an upgraded version of the Block 1 aircraft, which had inherited some of its systems from the Prowler. All Growlers in the current inventory are Block 2. The upgrades provided an advanced APG-79 radar that delivers improved target-location cueing. Software upgrades were also included in the block:

> This version is fitted with the AN/APG-79 multi-mode radar with passive detection mode and active radar suppression, ALQ-218(V)2 digital radar warning receiver and ALE-47 countermeasures dispenser.
>
> The APG-79 Active Electronically Scanned Array (AESA) radar provides air-to-air and air-to-ground capability with detection, targeting, tracking and protection modes. The interleaved radar modes include real beam-mapping mode and synthetic aperture radar mode with air-to-air search, air-to-air tracking, sea surface search and ground moving target indication (GMTI) and tracking. The radar has an advanced four-channel receiver-exciter which provides wide bandwidth capability and the ability to generate a wide range of waveforms for electronic warfare, air-to-air and air-to-ground operation. It also has the ability to operate in multiple air-to-air and air-to-ground modes simultaneously. The multi-mission advanced tactical terminal (MATT) allows for satellite communications.
>
> The AN/ALQ-218(V)2, developed by Northrop Grumman Electronic Systems, is a digital variant of the improved capabilities (ICAP) III system deployed on the U.S. Navy's EA-6B Prowler aircraft. The system's antennas are located on the port and starboard sides of

[15] Ibid.

[16] Author's interview on March 2, 2016, with EA-18G naval aviators from Commander Electronic Attack Wing Pacific, NAS Whidbey Island, Washington. For more on carriers, see CRS Report RS20643, *Navy Ford (CVN-78) Class Aircraft Carrier Program: Background and Issues for Congress*, by (name redacted). For more background on the Growler, see "EA-18G Growler," Military Periscope, accessed November 10, 2015, at https://www.militaryperiscope.com/weapons/aircraft/p-r-e/w0005638.html

[17] "EA-18G Growler," Military Periscope, accessed November 10, 2015, at https://www.militaryperiscope.com/weapons/aircraft/p-r-e/w0005638.html.

> the nose, the engine bays, in the wingtip pods, and to the aft of the cockpit, providing 360-degree azimuthal cover. The passive countermeasures system provides threat detection, identification and location. In Block 2 aircraft, the ALQ-218 is able to hand off target data to other airborne, land or ground attack platforms.[18]

EA-18G Procurement, Sustainment, and Modernization Efforts

According to the Navy, "the EA-18G's electronic attack upgrades meet or exceed EA-6B AEA capability to detect, identify, locate and suppress hostile emitters; provide enhanced connectivity to National, Theater and strike assets."[19]

"During February 2010, the USN published its USN FY2011 budget justification documentation in which the complete EA-18G program was outlined as comprising 114 aircraft. The Navy's procurement schemata broke down into 34 'prior year' aircraft, 22 in FY 2009 aircraft, 22 in FY2010 aircraft, 12 in FY2011 aircraft and 24 in FY2012 aircraft."[20] The additional aircraft (beyond the original program-of-record figure) were required to maintain three expeditionary squadrons (VAQs 132,138, and 135) that had been originally scheduled for deactivation circa 2012.[21]

The Navy's budget request for FY2014 revealed its desire to procure an additional 21 Growler aircraft during the fiscal year to create two new expeditionary electronic attack squadrons; the squadrons would serve as a functional replacement for the USMC's four squadrons of EA-6B Prowlers post-2019. This procurement would create a pool of five expeditionary VAQ squadrons to support U.S. and coalition military operations and bring the service's total EA-18G procurement up from 114 (the 2013 program of record) to 135.[22] In January 2014, Boeing announced it had delivered to the Navy the 100th EA-18G.[23]

Congress allocated $1.46 billion to procure 15 additional Growlers in FY2015 and $660 million to procure 7 Growlers in FY2016. Current orders take Growler and Super Hornet production through the end of 2016. The Navy should receive three additional EA-18G aircraft from Boeing as a result of a settlement from the 23-year A-12 aircraft litigation dispute.[24] These aircraft are scheduled to be delivered in July 2016, October 2016, and March 2017.

The Navy has stated that since the EA-18G is a modified F/A-18F, some support costs are common and therefore more efficiently executed out of one budget line. These common costs are budgeted in the F/A-18 E/F budget line. Current procurement programs that support the EA-18G but are under the F-18 funding line are

- E/F & EA-18G Correction of Operational Discrepancies;

[18] Ibid.

[19] Department of Defense Fiscal Year FY2017 President's Budget Submission, Navy Justification book, Volume 1, Aircraft Procurement, Navy Budget Activity 01-04, at http://www.secnav.navy.mil/fmc/fmb/Documents/17pres/APN_BA1-4_BOOK.pdf.

[20] IHS Jane's, "C4ISR & Mission Systems: Air, Boeing EA-18G Growler," posted September 19, 2015.

[21] Ibid.

[22] "EA-18G Growler," Military Periscope, accessed November 10, 2016, at https://www.militaryperiscope.com/weapons/aircraft/p-r-e/w0005638.html.

[23] "Boing Delivers 100th EA-18G Growlers to the U.S. Navy," at http://boeing.mediaroom.com/Boeing-Delivers-100th-EA-18G-Growler-to-US-Navy.

[24] "Boeing, General Dynamics reach $400 million A-12 settlement with U.S. Navy," Reuters, January 23, 2014, at http://www.reuters.com/article/us-boeing-generaldynamics-settlement-idUSBREA0M22820140124.

- Core Avionics Improvements;
- APG-79 AESA Radar;
- EA-18G Unique Operational, Safety, and Improvement Program (OSIP);[25] and
- F/A 18E/F and EA-18G Service Life Extension Program (SLEP).[26]

The Navy has created the EA-18G Development and EA-18 Squadrons programs to support development, test and evaluation, and modernization of the continued growth of the EA-18G Growler fleet.

As part of this, the Navy is developing a major capability to replace the current ALQ-99: the Next Generation Jammer (NGJ). Raytheon announced that its "Next Generation Jammer solution was selected by the U.S. Navy in 2013 to replace the legacy ALQ-99 systems used on the EA-18G and EA-6B aircraft. In [April], 2016, the U.S. Navy awarded Raytheon a $1 billion Next Generation Jammer Engineering and Manufacturing Development contract."[27]

E/F and EA-18G Correction of Operational Discrepancies

Another program funding Growler readiness is the F/A-18E/F Correction of Discrepancies Operational Safety Improvement Program (OSIP). To correct discrepancies discovered during testing and development, the Navy sometimes incorporates fixes into production aircraft; however, "when this cannot be done due to time constraints, retrofit of the changes into already delivered aircraft requires funding through the Aircraft Modification Program."[28] The program aims to correct operational discrepancies that have been discovered during testing and evaluations, sustainment activities, engineering analysis, standard depot-level evaluations, and normal fleet operations.[29]

Core Avionics Improvements

The Navy uses the Core Avionics Improvement program "to retrofit upgrades, manage obsolescence issues, and improvements to various avionics systems that have been or are being incorporated into fleet aircraft, to provide updates to Automated Maintenance Environment (AME) and the integrated electronic technical manuals, and to provide mission planning updates."[30] This program allows the Navy to maintain a fleet of aircraft that is continuously updating its avionics and manuals to support the maintenance of those systems.

[25] Operational Safety and Improvement Program (OSIP) definition: OSIP is a Navy acquisition term used for the modification of aircraft. OSIP funds the procurement and installation of modification kits for incorporation of improvements into in-service aircraft to correct deficiencies and improve operational capabilities. OSIPs are used for both sustainment (to correct safety issues) and capability or improvement efforts (to retrofit those improvements) that are not able to be forward fit into aircraft on the production line.

[26] Service Life Extension Program (SLEP) definition: SLEP is a defense acquisition term for a modification(s) to fielded systems undertaken to extend the life of the system beyond what was previously planned; definition taken from the Defense Acquisition University Glossary of Acronyms and Terms, at https://dap.dau.mil/glossary/Pages/2627.aspx.

[27] "Next Generation Jammer," Raytheon, at http://www.raytheon.com/capabilities/products/ngj/.

[28] From DOD FY17 President's Budget Submission justification book for Navy procurement accounts, Volume 2, Budget Activity 05, p. 68, at http://www.secnav.navy.mil/fmc/fmb/Documents/17pres/APN_BA5_BOOK.pdf.

[29] Ibid.

[30] Ibid., p. 162.

APG-79 Active Electronically Scanned Array (AESA) Radar

The Navy has developed the advanced APG-79 radar for its fleet of Super Hornets and Growlers. The AESA radar system was acquired for installation in subsequent Block II, Super Hornet, and Growler aircraft:

> [T]he integration of the APG-79 AESA radar system into the F/A-18E /F and EA-18G greatly improves the weapon system's threat detection range, high resolution synthetic aperture radar ground mapping and targeting capability, aircraft survivability and situational awareness. This OSIP also includes non-recurring efforts for reliability and operational safety improvements to the legacy APG-65 and APG-73 radars.[31]

EA-18G Unique OSIP

The EA-18G aircraft achieved initial operational capability (IOC) in FY2009. The Navy established this program and sought authorization to

> perform required safety of flight modifications, address obsolescence issues and incorporate system improvements. Funds are required to retrofit maintenance assemblies and achieve depot standup. Funding will support the retrofit of the ALQ-99 tactical jamming system. The Joint Tactical Terminal Receiver (JTTR) has been developed to replace the Multi-Mission Advanced Tactical Terminal (MATT) to address MATT obsolescence and capability deficiencies. OSIP funding will be used to retrofit the aircraft with JTTR at the completion of the development program. This OSIP also supports the procurement and fielding of operational test program sets.[32]

F/A-18E/F and EA-18G Service Life Extension Program (SLEP)

Service Life Extension Programs are created in many military aviation programs to extend the life of the fielded systems beyond what was previously planned. For the Navy's fleet of F-18s, this SLEP covers

> [i]ncorporation of structural and sub-systems enhancements and changes are required to extend the F/A-18E/F and EA-18G service life and maintain sufficient aircraft inventory to meet fleet operational requirements through FY2043. Structural enhancements and changes include resolution of discrepancies identified as a result of Service Life Assessment Program (SLAP) analysis and in-service experience.
>
> These enhancements and changes include: modifications to allow the entire airframe and aircraft sub-systems to extend flight hours and modifications to ensure landing gear, catapult and attachment components can extend total landings. The Navy has stated that the unacceptable alternative to retrofitting would be the failure to reach full fatigue life for these aircraft and to not correct the structural defects discovered on fatigue test articles. In many cases, the mission capability of the aircraft would be adversely affected in addition to its reduced service life. As a result, aircraft may be prematurely removed from useful service. SLAP analyzes the critical structural and sub-system areas to determine crack initiation, and then SLEP will produce Engineering Change Proposals (ECPs) for life limited locations.[33]

[31] Ibid., p. 179.

[32] Ibid., p. 199.

[33] Ibid., p. 214.

EA-18G Development

The Navy continues to focus on development for design and other improvements to the Growler. As such, the EA-18G Development Program focuses on "integration of avionics systems, integration of Jamming Techniques Optimization (JATO) improvements, evolutionary software upgrades and related testing. Continued advanced development engineering for improvements in reliability and maintainability are required to ensure maximum benefit is achieved through reduced cost of ownership and to provide enhanced availability."[34]

Next Generation Jammer (NGJ)

The NGJ is the next step in the evolution of airborne electronic attack (AEA). According to some military experts, "the NGJ is necessary to meet current and emerging EW gaps, to ensure kill chain unity against growing threat capabilities and capacity, and to keep pace with threat weapons systems advances and continuous expansion of the AEA mission area."[35] As seen in **Figure 3**, the NGJ will attach as a pod under the Growler's fuselage. The NGJ is described as

> an evolutionary acquisition program providing capability in three increments: Increment 1 (Mid-Band), Increment 2 (Low-Band) and Increment 3 (High-Band). The order of development—mid, low, and then high—was determined by the threat and available capability.[36]

The specific frequencies that each band will be designed to jam are classified. In its latest defense acquisition report,

> GAO stated that the NGJ program considers "achieving the necessary power within weight constraints to be the greatest risk." Additional risks include integration of the NGJ with the EA-18G and the potential for electromagnetic radiation to affect the reliability of missiles carried by the aircraft.
>
> The GAO noted that while the NGJ program has taken multiple steps to reduce design risk prior to development start—including approval for a higher pod weight by making trades with the EA-18G, and working groups to address NGJ and EA-18G software and hardware interoperability—it does not plan to test an early system prototype prior to the program's critical design review.
>
> Navy program officials told the GAO that prototyping and associated testing conducted to date had addressed the principal program risks.
>
> The Navy has planned a first test of a fully functional Increment 1 jamming pod for March 2019 with initial operational capability slated for June 2021.[37]

In April 2016, the Navy awarded Raytheon a $1 billion sole-source contract for Increment 1.[38]

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[34] From DOD FY2017 President's Budget Submission justification book for Navy TDT&E accounts, Volume 3, Budget Activity 05, p. 351, at http://www.secnav.navy.mil/fmc/fmb/Documents/17pres/RDTEN_BA5_Book.pdf.

[35] From DOD FY17 President's Budget Submission justification book for Navy TDT&E accounts, Volume 5, Budget Activity 07 p. 439. at http://www.secnav.navy.mil/fmc/fmb/Documents/17pres/RDTEN_BA7_Book.pdf.

[36] Ibid.

[37] "USN's Next Generation Jammer transitions into development," *IHS Jane's International Defence Review*, accessed January 4, 2016, at https://janes.ihs.com/Janes/Display/1766838.

[38] "The U.S. Navy awards Raytheon $1B Next Generation Jammer Engineering and Manufacturing Development contract," Raytheon website, at http://raytheon.mediaroom.com/2016-04-14-The-U-S-Navy-awards-Raytheon-1B-Next-Generation-Jammer-Engineering-and-Manufacturing-Development-contract.

Figure 3. Next Generation Jammer Prototype

Raytheon's NGJ Prototype mounted on a Gulfstream test jet

Source: Raytheon official website, at http://www.raytheon.com/news/feature/next_generation_jammer_flight.html.

Table 1 reflects the FY2017 budget submission for EA-18G procurement and EA-18G and Next Generation Jammer (NGJ) research, development, test, and evaluation programs derived from Navy budget justification books. It summarizes prior-year and estimated future-year expenditures for EA-18G sustainment and modernization programs either recently completed or currently in progress.

Table 1. Current EA-18G Sustainment and Next Generation Jammer Modernization Efforts

(in millions of dollars)

Procurement Items	Prior Years	Total Cost FY2015	Total Cost FY2016	Total Cost FY2017	Total Cost FY2018	Total Cost FY2019	Total Cost FY2020	Total Cost FY2021	Cost to Complete	Total Cost
EA-18G	10,742.177	1,503.534	660.0	—	—	—	—	—	—	12,905.711
EA-18G Aircraft Quantity	135	15	10	—	—	—	—	—	—	160
E/F & EA-18G Correction of Operational Discrepancies	673.239	81.766	161.992	143.920	154.022	159.695	212.716	207.641	144.785	1,939.776
Core Avionics Improvements	183.607	61.444	117.155	119.974	105.872	123.564	282.943	279.786	1,610.758	2,885.103
APG-79 AESA Radar	828.374	68.571	91.620	148.268	247.603	219.230	244.512	168.352	72.061	2,088.591
EA-18G Unique OSIP	70.600	19.049	10.760	22.632	37.590	85.061	46.423	58.973	120.818	471.906
F/A 18E/F and EA-18G SLEP	9.901	10.940	9.012	39.520	90.862	138.704	137.908	145.880	2,561.735	3,144.462
Total Procurement Items	**12,507.898**	**1,745.304**	**1,050.539**	**474.314**	**635.949**	**726.254**	**924.502**	**860.632**	**4,510.157**	**23,435.549**
RDT&E Items	**Prior Years**	**Total Cost FY2015**	**Total Cost FY2016**	**Total Cost FY2017**	**Total Cost FY2018**	**Total Cost FY2019**	**Total Cost FY2020**	**Total Cost FY2021**	**Cost to Complete**	**Total Cost**
EA-18G Development	1,815.500	18.653	46.921	116.761	164.999	142.820	65.642	67.405	Continuing	Continuing
Next Generation Jammer-Increment I	657.141	224.578	387.770	577.822	544.124	543.219	353.876	212.939	0.0	3,501.469
Next Generation Jammer-Increment II	0.0	0.0	13.0	52.065	76.424	156.730	230.696	194.291	886.204	1,609.410
Total RDT&E Items	**2,472.641**	**243.231**	**447.691**	**746.648**	**785.547**	**842.769**	**650.214**	**474.635**	**886.204**	**7,549.58**[a]

Source: Prepared by CRS based on justification books for Navy procurement accounts and Navy research, development, test, and evaluation accounts for FY2017 and prior years.

a. Cost to Compete and Total Cost includes only Next Generation Jammer RDT&E and not EA-18G Development program, as it is a continuing program.

Northrop Grumman EA-6B Prowler

Figure 4. EA-6B Prowler

Source: U.S. Navy Air Systems Command official website, Aircraft and Weapons, EA-6B Prowler, at http://www.navair.navy.mil/index.cfm?fuseaction=home.display&key=C8B54023-C006-4699-BD20-9A45FBA02B9A.

The EA-6B Prowler is a four-seat, long-range, all-weather aircraft with advanced electronic countermeasures capability. As shown in **Figure 4**, it is a twin-engine, mid-wing-configured aircraft. [39] The pilot and an electronic countermeasures officer (ECMO) fly side-by-side in the front cockpit, while two more ECMOs are seated in the rear of the cockpit. "The EA-6B weapons systems include the ALQ-218 receiver, ALQ-99 tactical jamming pod, USQ-113 communications jammer and AGM-88 High-Speed Anti-Radiation Missile (HARM)."[40] The Marine Corps is expected to fly the EA-6B until 2019 retirement, unless the fiscal or operational environment causes a change that may extend its service.

As noted earlier, the Navy transitioned to the EA-18G Growler (away from the Prowler) due to its increased capability and cost savings by having several avionic subsystems common to its current primary strike fighter, the F/A-18F Super Hornet. Its primary mission has been to jam enemy radars and to destroy them with missiles.

Background

The EA-6B is a modified A-6 Intruder attack aircraft design. The EA-6B represented a leap ahead in EW/electronic countermeasures (ECM) from its predecessor, the EA-6A.[41] The Prowler was to replace the Marines' Douglas EF-10B Skyknight.[42] Entering squadron service in 1963, the A-6

[39] U.S. Naval Air Systems Command official website, at http://www.navair.navy.mil/index.cfm?fuseaction=home.display&key=C8B54023-C006-4699-BD20-9A45FBA02B9A.

[40] Ibid.

[41] "EA-6B Prowler EW/ECM aircraft," Military Periscope, accessed February 23, 2015, at https://www.militaryperiscope.com/weapons/aircraft/p-r-e/w0003131.html.

[42] See IHS Jane's Aircraft Upgrades, Northrup Grumman EA-6B Prowler, posted January 7, 2016, at https://janes.ihs.com/Janes/Display/1337569.

was a workhorse in Vietnam and retired from service in 1997. The next upgrade for the Prowler began when Northrop Grumman engineers received a contract for an advanced electronic attack aircraft:

> A development contract was issued in fall of 1966 for EA-6B; externally similar to the basic A-6 except a longer nose which encloses a four-seat cockpit and large pod on fin. The first flight took place on May 25, 1968. Delivery of first 12 production aircraft started in January 1971 and the last of 170 Prowlers was delivered on July 29, 1991. With the retirement of the U.S. Air Force's EF-111 Ravens, Prowlers acquired sole responsibility for tactical EW missions for both the U.S. Navy and the U.S. Air Force from the early 1990's until the acquisition of the EA-18G Growler. The U.S. Navy EA-6B Prowler fleet went through a number of capability enhancements, the latest being Improved CAPability (ICAP) III.
>
> The USMC received its first ICAP III aircraft on April 7, 2010. The aircraft was the first of five delivered to VMAQ-4, which deployed to Afghanistan with the new model on April 21, 2011. The final upgraded ICAP III Prowler was delivered in September 2011.
>
> In the Navy, the EA-6B has been replaced by EA-18G Growler and the final Navy Prowler flight was on 27 June 2015. The Marine Corps will retain all remaining 20 Prowlers until 2019.[43]

All USMC Prowlers are assigned to one of four Marine Tactical Electronic Warfare (VMAQ) squadrons located at Marine Corps Air Station (MCAS) Cherry Point, North Carolina. Each squadron operates five aircraft and is land-based, although they are capable of operating aboard U.S. Navy aircraft carriers. Phase-out of the USMC Prowlers is scheduled to begin in 2016.

The Prowler has been involved in numerous military operations since Vietnam. After the September 11, 2001, attacks, beginning in October 2001, Prowlers supported Navy, Air Force, and Marine Corps strikes against Taliban and Al-Qaida units in Afghanistan.[44]

Prowlers likewise played a significant role in the initial success of Operation Iraqi Freedom by conducting EW missions against the Iraqi IADS and minimizing the threat that Iraqi SAMs posed to coalition air forces.[45] The Prowler reportedly played "a key role in psychological operations in Iraq, taking control of insurgent radio broadcasts and disrupting the cell phone traffic with the BAE Systems USQ-113 communications jammer."[46] In addition, the EA-6B jammer can thwart cell phone communications that detonate certain improvised explosive devices (IEDs).

In 2014 and 2015, both Navy Prowlers (before they were retired) and Marine Prowlers "conducted jamming missions against Islamic State militants in Iraq and Syria.... The aircraft is also capable of detecting Islamic State signals and gathering intelligence."[47]

[43] See IHS Jane's Aircraft Upgrades, Northrup Grumman EA-6B Prowler, posted January 7, 2016, at https://janes.ihs.com/Janes/Display/1337569.

[44] "EA-6B Prowler EW/ECM aircraft," Military Periscope, accessed February 23, 2015, at https://www.militaryperiscope.com/weapons/aircraft/p-r-e/w0003131.html.

[45] Firsthand knowledge of the author as a participant and veteran of Operation Iraqi Freedom who flew missions with EA-6B Prowlers.

[46] "EA-6B Prowler EW/ECM aircraft," Military Periscope, accessed February 23, 2015, at https://www.militaryperiscope.com/weapons/aircraft/p-r-e/w0003131.html.

[47] Ibid.

EA-6 Sustainment Efforts [48]

With the EA-18G Growler replacing the Prowlers for the Navy and the planned phase-out of USMC Prowlers beginning in 2016, the EA-6B is not undergoing any major upgrades and is in sustainment only until the fleet is retired in 2019.[49]

The EA-6B Prowler is a low-density, high-demand (LD/HD)[50] platform that is 40-plus years old.

> Considerable modifications have been required in two basic categories to keep the systems viable: weapons delivery and airframe reliability. Weapons delivery includes Airborne Electronic Attack (AEA) systems and its ancillary equipment. Several systems on the aircraft are based on obsolete software and techniques. Modifications are required to maintain safety of flight as the platform ages; Fatigue Life Expended (FLE), advanced corrosion, and tired iron must be addressed. These investments are required to keep the aircraft and its systems/subsystems viable until the platform is retired.[51]

Two main initiatives in the current program of record are (1) EA-6B Avionics and Structural Improvements and (2) Improved Capabilities III (ICAP III) system modifications. In addition, while the Department of the Navy is not investing in RDT&E to exclusively support the EA-6B, it continues to support efforts to improve current and future EW capabilities for both the Navy and Marine Corps aircraft under the "Electronic Warfare Development" program element.

EA-6B Avionics and Structural Improvements

The Department of the Navy has stated that it will continue to maintain the current EA-6Bs for the Marine Corps until 2016. As such, this Operational Safety and Improvement Program will sustain the airframe and avionics portions of the asset, covering

> EA-6B structural, systems, sub-systems, and avionics modifications and improvement to mission degrading deficiencies discovered during test reviews, flight line inspections, and preventive maintenance inspections related to reliability, maintainability, sustainability, training, and safety of flight.

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[48] Definition for Sustainment, Modernization and Recapitalization are from the Defense Acquisition University, at https://acc.dau.mil/CommunityBrowser.aspx?id=495015&lang=en-US.

Sustainment involves the supportability of fielded systems and their subsequent life cycle product support—from initial procurement to disposal. Sustainment begins when any portion of the production quantity has been fielded for operational use.

Modernization is a process by which state-of-the-art technologies are inserted into weapon systems to increase reliability, lower sustainment costs, and increase the war-fighting capability of a system to meet evolving customer requirements throughout an indefinite service life.

Recapitalization, or RECAP, is the rebuild and/or systematic upgrade of currently fielded systems to ensure operational readiness. Recapitalization is different from daily sustainment operations in that it involves a rebuild, replacement, modernization and/or restoration of the item. Objectives of a recapitalization project can include extending service life, reducing costs, improving system reliability, and enhancing capability. Funding for recapitalization is provided mostly from procurement accounts.

[49] From EA-6B sustainment and modernization efforts derived from Department of Defense FY 2017 President's Budget submission Navy Justification Book, Volume 2, p. 3. at http://www.secnav.navy.mil/fmc/fmb/Documents/17pres/APN_BA5_BOOK.pdf.

[50] *Low-density/High-demand* (LDHD) military capability means a combat, combat support or service support capability, unit, system, or occupational specialty that the Secretary of Defense determines has funding, equipment, or personnel levels that are substantially below the levels required to fully meet or sustain actual or expected operational requirements set by regional commanders.

[51] From EA-6B sustainment and modernization efforts derived from Department of Defense FY 2017 Navy Justification Book, Volume 2, p. 2. at http://www.secnav.navy.mil/fmc/fmb/Documents/17pres/APN_BA5_BOOK.pdf.

> Aircraft Structures Improvements includes required modifications based on fatigue life analysis and aircraft changes to ensure EA-6B aircraft availability, reliability, and maintainability of airframe structural components through FY19.
>
> Funds provide support to all EA-6B airframe readiness, hardware readiness, electrical component readiness, obsolescence prevention, inspections, installations, and safety of flight improvements throughout remaining airframe service. Fund application to the structure, system/subsystem, and avionics deficiencies will be made to ensure aircraft service readiness and reliability.[52]

ICAP III System Modifications

While operational, the Prowler's electronic capabilities require maintenance and improvements, largely in the aircraft's command and control capabilities. The Navy uses this program to cover

> the continuing EA-6B Improved Capabilities III (ICAP III) system modifications. Specifically, the modification program replaced the ALQ-99 Receiver System with the more capable ALQ-218 receiver system, replaced the older TDY-43 display system with a new Commercial Off The Shelf (COTS) based display system for the Pilot and three ECMOs. It also provided new data link capabilities to communicate and pass integrated targeting and convoy protection when using the LITENING Pod system on AV-8B Harrier aircraft.[53]

Airborne Electronic Attack (AEA) Systems

AEA systems require maintenance and periodic upgrades to stay ahead of dynamic or emerging electronic warfare capabilities of other nations. The Navy uses the AEA Systems program to maintain

> the ALQ-99 Tactical Jamming System used by the Prowler to ensure continued system availability until the Next Generation Jammer reaches Full Operational Capability (FOC). AEA System procurements and related efforts are required to combat emerging electronic warfare technology and systems. Modifications to current AEA products used on multiple platforms are needed to ensure that sufficient AEA capability is available to meet warfighter requirements. Modifications budgeted and programmed include: procurement and enhancement of Low Band Transmitter Antenna Group inventory, AN/ALQ-99 Tactical Jamming System upgrades and related sustainability, capability, and viability modifications.[54]

Electronic Warfare (EW) Development

As discussed earlier, electronic warfare encompasses a range of interrelated systems. For combat efficiency, upgrades should be compatible across the fleet. This RDT&E program element includes development of EW systems for Navy and Marine Corps tactical aircraft, Marine Corps "helicopters, surface combatants, data link vulnerability assessments, precision targeting, radio frequency jammers, and development and testing of electronic warfare devices for emerging threats and emergency contingencies."[55] This element also includes development of Aircraft

[52] Ibid., p. 3.

[53] Ibid., p. 8.

[54] Ibid., pp. 17-18.

[55] From Department of Defense FY2017 President's Budget Submission Navy research, development, test, and evaluation Justification Book, Volume 3, p. 365, at http://www.secnav.navy.mil/fmc/fmb/Documents/17pres/RDTEN_BA5_Book.pdf.

Survivability Equipment (ASE) and EW/countermeasures solutions for the Navy, Marine Corps, and Coalition aircraft to include studies and evaluations of current and future aircraft threats, modeling and simulation for improved countermeasure capabilities, and development and testing to address new and emerging threats. EW programs under this element are

- EW Counter Response,
- EW Technical Development and Test & Evaluation (T&E),
- Tactical Air EW,
- Technology Development,
- Assault Survivability Optimization,
- Marine Air-Ground Task Force (MAGTF) EW Aviation Development, and
- MAGTF EW Interoperability Development.[56]

These smaller Electronic Attack (AEA) programs are designed to achieve Navy and Marine Corps state-of-the-art signal exploitation, processing, display techniques, improved tactics, and jamming capabilities against EW threats. Many background activities are required to maintain electronic attack, electronic countermeasures, and electronic signal communication capability for fleet aircraft. In addition, the Navy believes that EW technology research to develop these capabilities will enable the United States to stay ahead of adversarial EW threats.

The *EW Counter Response* program "funds the continued development and integration of all EW and Electronic Attack systems for the U.S. Navy electronic attack aircraft."[57] Efforts are primarily risk-reduction activities to support the upgrade of the ALQ-99 Tactical Jamming System (TJS) and the electronic attack Jammer Techniques Optimization (JATO) project. The program also funds testing to address and counter new and evolving radar and communications threats in support of existing and emerging systems such as the EA-6B, EA-18G, and Next Generation Jammer (NGJ).

The *EW Technical Development and Test & Evaluation (T&E)* program focuses on providing data-link vulnerability assessments, and developing and testing electronic warfare devices for emerging threats and emergency contingencies.

The *Tactical Air EW* program supports various countermeasures to include new towed decoys and upgrades to EW sensors onboard Department of the Navy aircraft.

The *Technology Development* program is used for quick-reaction prototyping of EW and countermeasures for survivability against emerging and previously unknown threats.

The *Assault Survivability Optimization* program was established by the Navy to

> fill Navy and Marine Corps aircraft survivability gaps against current and future threat systems using current and advanced technology expendable countermeasures, as well as improvements in Aircraft Survivability Equipment (ASE) systems. The project is required for DON aircraft self-protection against man-portable missiles (MANPADs), especially due the accelerated proliferation of these threats.[58]

The *MAGTF EW Aviation Development* project supports the three EW subdivisions for the Marine Corps by developing various payloads designed to be carried "on a variety of MAGTF air

[56] Ibid.

[57] Ibid., p. 368.

[58] Ibid., p. 399.

and ground assets to include the ALQ-231 Intrepid Tiger Pod, which the Marine Corps intends to be flown by unmanned aerial vehicles (UAVs)."[59]

To facilitate successful amphibious operations, Marine Corps aircraft and ground assets employ their EW capabilities through an "adaptable, scalable, and open architecture philosophy to reduce stove-pipe solutions but enable future growth at a reduced operational and sustainment cost."[60]

The *MAGTF EW Interoperability Development* project was created to fund and support efforts that collaborate across assets, as opposed to efforts limited to specific military resources, vehicles, or aircraft. In this context, Prowler modifications are aimed at ensuring combat capability up to the date of retirement from the fleet.

Table 2 reflects the FY2017 budget submission for EA-6B procurement and EW research, development, test, and evaluation programs derived from Navy budget justification books. It summarizes prior-year and estimated future-year expenditures for EA-6B sustainment and modernization programs that are either recently completed or currently in progress.

[59] Ibid., p. 407.

[60] Ibid., p. 415.

Table 2. Current EA-6B Sustainment and EW Modernization Efforts

(in millions of dollars)

Procurement Items	**Prior Years**	**Total Cost FY2015**	**Total Cost FY2016**	**Total Cost FY2017**	**Total Cost FY2018**	**Total Cost FY2019**	**Total Cost FY2020**	**Total Cost FY2021**	**Cost to Complete**	**Total Cost**
EA-6B Avionics and Structural Improvements	1,143.880	4.013	0.268	—	—	—	—	—	—	1,148.161
ICAP III	512.607	6.686	7.531	—	—	—	—	—	—	527.006
AEA Systems	199.078	44.768	36.233	51.900	52.818	51.878	58.282	70.078	315.316	880.351
Total Procurement Items	**1,364.565**	**55.649**	**44.032**	**51.900**	**52.818**	**51.878**	**58.282**	**70.078**	**315.316**	**2,555.518**
RDT&E Items	Prior Years	Total Cost FY2015	Total Cost FY2016	Total Cost FY2017	Total Cost FY2018	Total Cost FY2019	Total Cost FY2020	Total Cost FY2021	Cost to Complete	Total Cost
EW Counter Response	447.063	15.026	11.890	15.389	16.395	17.633	18.009	18.389	Continuing	Continuing
EW Technical Development and T&E	0.0	1.112	1.629	1.585	1.585	1.617	1.652	1.685	Continuing	Continuing
Tactical Air EW	468.547	11.113	6.594	3.927	2.074	2.069	2.089	0.0	0.0	496.413
Technology Development	0.0	0.0	0.0	2.016	2.502	6.316	6.382	8.652	Continuing	Continuing
Assault Survivability Optimization	0.0	0.0	0.0	3.375	0.849	0.835	0.836	0.858	Continuing	Continuing
MAGTF EW Aviation	0.0	0.0	0.0	20.817	20.776	2.984	2.794	2.862	Continuing	Continuing
MAGTF EW Interoperability Development	0.0	0.0	0.0	1.657	1.628	0.945	0.965	0.986	Continuing	Continuing
Total EW RDT&E Items	**915.610**	**27.251**	**20.113**	**48.766**	**45.809**	**32.399**	**32.727**	**33.432**	**Continuing**	**Continuing**

Source: Prepared by CRS based on justification books for Navy procurement accounts and Navy research, development, test, and evaluation accounts for FY2017 and prior years.

Lockheed Martin EC-130H Compass Call

Figure 5. EC-130H Compass Call

Source: U.S. Air Force official website, EC-130H Compass Call Fact Sheet, September 23, 2015, at http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104550/ec-130h-compass-call.aspx.

The EC-130H Compass Call is an EW system placed on a modified version of the C-130 Hercules airframe. An Air Force decision to divest half of the EC-130H Compass Call fleet in FY2016, largely in response to Service and DOD priorities in implementing the Budget Control Act, with amendments, was deferred to FY2019. In March 2016, Secretary of the Air Force Deborah James testified before Congress on the annual Air Force Posture Statement and commented on the Compass Call, stating that "we are now proposing to re-phase the retirement of the A-10 (Thunderbolt II) and the (EC-130H) Compass Call aircraft."[61]

James continued, stating that "the bottom line here is we are not proposing to retire any of these aircraft in (fiscal year 2017). We do believe that we will need to divest these weapons systems in the future, but this (year's change) will maintain a sufficient number of fighter and electronic attack aircraft across the force in support of current operations."[62] The Compass Call aims to be a viable electronic attack asset into the foreseeable future. The Air Force describes the EC-130H Compass Call a heavily modified version of the C-130 Hercules primarily designed to be an airborne communications electronic attack platform. Its primary mission has been to disrupt and jam enemy air defense radars. Furthermore:

[61] Hailey Haux, "James, Welsh testify before Congress" March 4, 2016, at http://www.af.mil/News/ArticleDisplay/tabid/223/Article/685943/james-welsh-testify-before-congress.aspx.

[62] Ibid.

The system disrupts enemy command and control (C2) communications and limits adversary coordination essential for enemy force management. The Compass Call system employs offensive counter-information and electronic attack (EA) capabilities in support of U.S. and coalition tactical air, surface, and special operations forces. The EC-130H, EA-6B or EA-18G, and F-16CM, form what is called the SEAD triad working together to defeat adversarial air defense systems. Programmed upgrades have expanded its mission by procuring a secondary EA capability against early warning and acquisition radars. The EC-130H continuously tests new capabilities and tactics to respond to emerging threats and requests from combatant commanders.[63]

The EC-130H aircraft carries a combat crew of 13 people. Four members are responsible for aircraft flight and navigation (aircraft commander, co-pilot, navigator, and flight engineer), while nine members operate and employ the EA mission equipment permanently integrated in the cargo/mission compartment. The mission crew includes the mission crew commander (an electronic warfare officer (EWO), weapon system officer (also EWO), mission crew supervisor (an experienced cryptologic linguist), four analysis operators (linguists), one acquisition operator, and an airborne maintenance technician.[65]

SEAD Triad[64]

The Suppression of Enemy Air Defenses (SEAD) Triad was an EW tactic developed by the U.S. Air Force taking lessons learned during the Vietnam War. By 1981, the Air Force focused on the F-4G Wild Weasel as HARM shooters, the EF-111 Aardvark as radar jammers, and the EC-130H Compass Call as communication jammers as combined force to suppress or limit an enemy's IADS. When the EA-6B Prowler was developed, it was added with the F-4G as a HARM shooter while also having the ability to jam radar and communication frequencies. Today, the F-16CM is replacing the F-4G for the Air Force, while the EA-18G Growler is replacing the Prowler. The Compass Call remains the primary communication jammer.

The EC-130H fleet of 14 airplanes is composed of a mix of two versions of aircraft: Baseline 1 and 2. The first Baseline 2 aircraft was received on February 20, 2014, at Davis-Monthan Air Force Base (AFB), Arizona.

Baseline 1

The version of the Compass Call that was delivered to the Air Force was called Baseline 1.

The Block 35 Baseline 1 EC-130H provides the Air Force with additional capabilities to jam communication, early warning/acquisition radar and navigation systems through higher effective radiated power, extended frequency range, and insertion of digital signal processing versus earlier EC-130Hs. Baseline 1 aircraft have the flexibility to keep pace with adversary use of emerging technology. It is highly reconfigurable and permits incorporation of clip-ins with less crew impact. It promotes enhanced crew proficiency, maintenance and sustainment with a common fleet configuration, new operator interface, increased reliability, and better fault detection.[66]

[63] From the U.S. Air Force EC-130E Fact Sheet, September 23, 2015, at http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104550/ec-130h-compass-call.aspx.

[64] James R. Brungess, *1994. Setting the Context: Suppression Of Enemy Air Defenses And Joint War Fighting In An Uncertain World.* n.p.: Maxwell Air Force Base, Alabama (Air University Press, Washington, DC); for sale by the Supt. of Docs., U.S. G.P.O., 1994, NDU Libraries Catalog, EBSCOhost (accessed June 2, 2016).

[65] From the U.S. Air Force EC-130E Fact Sheet, September 23, 2015, at http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104550/ec-130h-compass-call.aspx.

[66] Ibid.

Baseline 2

The most current version is the Baseline 2, and it brought with it a number of upgrades to ease operator workload and improve effectiveness. The Air Force states that Baseline 2 brings in

> [c]lip-in capabilities integrated into the operating system that, utilizing automated resource management, are able to be employed seamlessly with legacy capabilities. Improved external communications allow Compass Call crews to maintain situational awareness and connectivity in dynamic operational and tactical environments.
>
> The Delivery of Baseline-2 provides the DOD with the equivalent of a fifth generation electronic attack capability. A majority of the improvements found in the EC-130H Compass Call Baseline-2 are classified modifications to the mission system that enhance precision and increase attack capacity. Additionally, the system was redesigned to expand the "plug-and-play" quick reaction capability aspect, which has historically allowed the program to counter unique "one-off" high profile threats. Aircraft communication capabilities are improved with expansion of satellite communications connectivity compatible with emerging DOD architectures, increased multi-asset coordination nets, and upgraded data-link terminals. Furthermore, modifications to the airframe in Baseline-2 provide improved aircraft performance and survivability.[67]

Planned Baseline 3 modifications are expected to provide additional electronic warfare capabilities.

Background[68]

As the Air Force was developing its SEAD triad in the late 1970s, the need for a communication jammer was evident:

> During the late 1970s, the USAF produced a requirement for a Quick Reaction Capability (QRC) Command, Control and Communications (C3) countermeasures aircraft that would be able to disrupt and degrade the C3 elements of an integrated air defense network from stand-off ranges. A lack of funding prevented work starting on such a system until the beginning of the following decade. Circa 1980/1981, the then Lockheed Aircraft Service (LAS) company of Ontario, California was awarded a contract to design, integrate, install and flight test a C-130 based C3 countermeasures mission suite, with the resultant platform being code-named "Rivet Fire" and then "Compass Call."[69]

The Compass Call had its first flight in 1981, was delivered to the Air Force in 1982, and reached initial operating capability in 1983. Over its 32-year operational life, the aircraft has demonstrated its ability to affect enemy command and control networks in multiple military operations, including Kosovo, Haiti, Panama, Libya, Iraq, Serbia, and Afghanistan. In the past 15 years, the 41st ECS has been continuously deployed in support of Afghanistan operations, flying more than 6,800 sorties since 2002. The 43rd ECS, from 2010 to 2015, provided more than 26,000 hours of EA in support of U.S. operations in Iraq.[70]

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[67] Ibid.

[68] IHS Jane's C4ISR & Mission Systems: Air, Boeing EC-130H "Compass Call," pp. 8-9, posted September 19, 2015 and from the U.S. Air Force EC-130E Fact Sheet, September 23, 2015, at http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104550/ec-130h-compass-call.aspx.

[69] Jane's C4ISR & Mission Systems: Air, Boeing EC-130H "Compass Call," pp. 8-9, posted September 19, 2015.

[70] From the U.S. Air Force EC-130E Fact Sheet, September 23, 2015, at http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104550/ec-130h-compass-call.aspx.

All Compass Call aircraft are assigned to Air Combat Command. The EC-130H is operated by the 55th Electronic Combat Group (ECG), consisting of two operational squadrons (41st and 43rd Electronic Combat Squadron [ECS]). The 55th ECG is a tenant unit of the 355 Fighter Wing at Davis-Monthan AFB, Arizona. Although located at Davis-Monthan, the group reports to 55th Wing at Offutt AFB, Nebraska.

EC-130H Compass Call Sustainment and Modernization Efforts

The Air Force believes that EC-130H mission equipment must continue to evolve to keep pace with the emerging adversary developments in new communications and sensor technology, as well as the use of rapidly advancing commercial technology. Its three-year cycle for technological upgrades in the aircraft's primary EW systems aims to stay ahead of other nations' countermeasures:

> The EC-130H Compass Call inventory at the beginning of FY2017 includes the following resources: 15 EC-130H total active inventory (TAI)—10 aircraft are Primary Mission Aircraft inventory (PMAI), four aircraft are Backup Aircraft Inventory (BAI), and one aircraft is a NEC-130H test aircraft inventory, one Weapon System Trainer (WST, a.k.a. flight deck simulator) and two Compass Call Mission Crew Simulators (CCMCS).
>
> The EC-130H Compass Call program seeks to employ an incremental baseline upgrade acquisition strategy that puts capability into the warfighter's hands as soon as practical and ensures each iteration of the weapon system is effective against the highest priority threats. A new baseline of capability is fielded approximately every three years. Capabilities inserted into each baseline are planned in advance, based on warfighter inputs. Executive Management Reviews are held to review and "lock" baseline content as production nears. Kit components contracted for purchase and integration in a given baseline upgrade are bought in the first year of the procurement funding cycle and are installed in the next year.[71]

FY2017 funding aims to procure kits as well as installation of such hardware during the aircraft depot maintenance/modification cycle as per the FY2016 NDAA language, which added $28.7 million to the original request of $68.415 million, for a total of $97.115 million.[72] Obsolescence and Diminishing Manufacturing Sources (DMS)/Vanishing Vendor Items (VVI) logistics mitigation efforts are addressed with each baseline upgrade, as well as annually as part of the sustainment responsibilities. The initial spares procurement funding in FY2017 will likely support the EC-130H mission in its theater of operations.

> The acquisition program manager plans to retire one TC-130 flight deck trainer (BAI aircraft) in FY2016 due to PDM requirements. The FY2017 funding increase of $103.5M restores the funding levels required to "buy back" the six Baseline 1 configured EC-130H (PMAI aircraft) identified for divestiture in FY2016. This additional funding will allow the Air Force to modify and sustain ten EC-130H Compass Call aircraft to a Baseline 2/Mid-Baseline 2 configuration.[73]

[71] From Department of Defense FY2017 President's Budget Submission Air Force Aircraft Procurement Justification Book, Volume 2, p. 271.

[72] P.L. 114-92, §4101 Procurement, Line 047.

[73] From Department of Defense FY2017 President's Budget Submission Air Force Aircraft Procurement Justification Book, Volume 2, p. 271.

Compass Call Modifications

According to the Air Force, production funds are required for modification kit production (hardware, firmware, and software) and installation of the systems and subsystems on each aircraft.

> Six Mid-Baseline 1 configured aircraft and four Baseline 2 configured aircraft are currently fielded (as of 4th Quarter, FY2015), plus five aircraft are in programmed depot maintenance (PDM) receiving the Mid-Baseline 2 and avionic viability program (AVP, a.k.a. glass cockpit) upgrade modifications.
>
> With each baseline, efforts focus on reliability and sustainability improvements, significant obsolete parts replacement, weight reduction, operator/maintenance simplification of primary mission equipment (PME) operations, and capability increases. Some examples are procurement of digital narrow band subsystem, counter radar subsystem, and 3rd Generation Special Purpose Emitter Array (SPEAR) system. Production funds are also used for avionics modifications to meet Communications, Navigation, Surveillance/Air Traffic Management (CNS/ATM) requirements and address avionics obsolescence issues. Similarly, baseline upgrades and enhancements will include necessary support equipment and training device/simulator modifications. The simulators replicate the fielded aircraft configurations, provide training and qualification of aircrew and ground personnel, and address training and certification obsolescence issues.[74]

Baseline 3

The Compass Call Baseline 3 is the next upgrade scheduled for the EC-130H. The upgrade will ensure that the aircraft remains a viable electronic attack asset for the Air Force. Baseline aircraft modifications will likely continue to address reliability and sustainability improvements, weight reduction, and capability increases.

> Baseline 3 will include, but is not limited to, new receiver suite, digital intercom and improved external communications. Subsequent modifications for Large Aircraft Infrared Counter Measures (LAIRCM) and Avionics are also included with the fielded aircraft. Similarly, new baselines will include necessary support equipment and simulator modifications.[75]

Electronic Warfare RDT&E

In addition to continuous investments in Compass Call RDT&E, the Air Force has a number of other RDT&E programs supporting EW to maintain up-to-date capabilities against emerging threats and emergency contingencies. Among these programs are

- EW Quick Reaction Capabilities,
- AEA Systems, and
- Threat Simulator Development.

The *EW Quick Reaction Capabilities* project establishes a capability to rapidly assess, develop, and demonstrate new EW concepts, techniques, and capabilities, as well as the required navigation technologies and capabilities in the context of systemic EW effects (EW-threat

[74] Ibid., p. 271.

[75] Ibid., p. 275.

interactions) in a congested/contested electromagnetic spectrum (EMS), system-of-systems (SoS) environment of the future.[76]

The *AEA Systems* project concentrates on

> the overall systems engineering, modeling and simulation, architecture and network requirements development, effectiveness assessment and requirements allocation to component systems of the AEA SoS. As the joint AEA SoS has evolved since its origination in 2004; it now includes the Navy EA-18G and its Next Generation Jammer (NGJ) increment 1 subsystem and the Air Force EC-130H Compass Call Baseline 3 configuration as stand-off components.[77]

The *Threat Simulator Development* project provides funding to support the Air Force EW Test Process, which

> provides a scientific methodology to ensure the effective disciplined and efficient testing of EW and avionics systems. Each capability or facility improvement is pursued in concert with the others to avoid duplicate capabilities, while at the same time producing the proper mix of test resources needed to support the AF EW Test Process and testing of EW systems which can be used in any action involving the use of electromagnetic and DE to control the electromagnetic spectrum or to attack the enemy.[78]

Table 3 reflects the FY2017 budget submission for EC-130H Compass Call sustainment and Compass Call and Air Force EW research, development, test, and evaluation programs derived from Air Force budget justification books. It summarizes prior-year and estimated future-year expenditures for EC-130H sustainment and modernization programs that are either recently completed or currently in progress.

[76] From Department of Defense FY2017 President's Budget Submission Air Force RDT&E Justification Book, Volume 2, at http://www.saffm.hq.af.mil/shared/media/document/AFD-160208-051.pdf.

[77] Ibid., p. 433.

[78] Ibid., p. 799.

Table 3. Current EC-130H Sustainment, Modernization and EW RDT&E Efforts

(in millions of dollars)

Procurement Items	Prior Years	Total Cost FY2015	Total Cost FY2016	Total Cost FY2017	Total Cost FY2018	Total Cost FY2019	Total Cost FY2020	Total Cost FY2021	Cost to Complete	Total Cost
Compass Call Mods (Baseline 2)	—	82.628	70.591	25.452	—	—	—	—	—	178.671
Baseline 3	—	—	26.399	104.805	101.982	45.511	37.259	37.946	5.500	359.402
Initial Spares/Repair Parts	—	12.458	10.128	50.172[a]	25.212	10.705	10.891	11.092	—	130.658
Total Procurement Items	**—**	**95.086**	**107.118**	**180.429**	**127.194**	**56.216**	**48.15**	**49.038**	**5.500**	**668.731**
RDT&E Items	**Prior Years**	**Total Cost FY2015**	**Total Cost FY2016**	**Total Cost FY2017**	**Total Cost FY2018**	**Total Cost FY2019**	**Total Cost FY2020**	**Total Cost FY2021**	**Cost to Complete**	**Total Cost**
Compass Call RDT&E	—	16.480	14.187	13.723	13.996	7.824	3.823	14.785	Continuing	Continuing
EW Quick Reaction Capabilities	—	27.632	27.119	30.912	28.107	29.975	30.598	31.282	Continuing	Continuing
AEA Systems	—	26.555	8.358	9.187	7.071	7.204	0.0	0.0	Continuing	Continuing
Threat Simulator Development	—	24.318	23.844	21.630	22.038	22.426	22.839	23.245	Continuing	Continuing
Total RDT&E Items	**—**	**94.985**	**73.508**	**75.452**	**71.212**	**67.429**	**57.26**	**69.312**	**Continuing**	**Continuing**

Source: Prepared by CRS based on justification books for Air Force procurement account and Air Force research, development, test, and evaluation accounts for FY2017 and prior years.

a. Includes $25.600 million Overseas Contingency Operations (OCO) funds.

Lockheed Martin F-16CM Block 50[79]

Figure 6. F-16CM Block 50 "Wild Weasel"

Source: U.S. Air Force official website, Air Force Photos, at http://www.af.mil/News/Photos.aspx?igphoto=2000031353.

Note: Wild Weasel-designated aircraft have the distinctive tail "flash" of "WW."

The F-16CM Block 50 (a.k.a. Block 50/52)[80] is generally called the SEAD "Wild Weasel" version of the F-16C/D Fighting Falcon. Deliveries of this version of the F-16 began in October 1991 for operational testing. The upgraded aircraft featured improved performance engines: a General Electric F110-GE-129 engine in the Block 50, and a Pratt & Whitney F100-PW-229 engine in Block 52. In 1993, Block 50D/52D changes included the full integration of the AGM-88 HARM Anti-Radiation Missiles via the ASQ-213 HARM Targeting System (HTS). The U.S. Air Force FY1997 buy of the Block 50/52 F-16 included incorporation of full color, multifunction displays (MFD) and a Modular Mission Computer (MMC). The MMC performs the functions of three previous generation computers. FY1997 F-16s were delivered beginning in mid-2000.

The Air Force's F-16CM "Wild Weasel" uses the HARM Targeting System (HTS). This targeting system is a cornerstone of the suppression of enemy air defense mission, providing substantial situational awareness to pilots on the types and locations of surface-to-air defense radars, as well as passing ranging solutions to the HARM missile when launched.[81]

[79] This section is broadly based on Jane's Aircraft Upgrades, from Jane's website, posted February 24, 2016.

[80] Note: The difference between a Block 50 and Block 52 is the engine. Block 50 aircraft carry the General Electric F110-GE-129 engine, while Block 52 carry the Pratt & Whitney F110-PW-229 engine. *Air Force Magazine, 2015 USAF Almanac*, p. 82.

[81] "High-speed Anti-Radiation Missile Targeting System" Fact Sheet, U.S. Air Force official website, at http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104602/high-speed-anti-radiation-missile-targeting-system.aspx.

Figure 7. HARM Targeting System (HTS) Pod

Source: U.S. Air Force official website, at http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104602/high-speed-anti-radiation-missile-targeting-system.aspx.

Note: In the latest R7 version, the HTS pod is mounted on the left side of the aircraft; in the previous R6 version, the pod was mounted on the right side.

HTS was developed to provide a significant advance in electronic attack technology and to fill the void left by the retirement of the F-4G Wild Weasel. The first squadron was operational in 1994. The Air Force has continued to purchase additional quantities of HTS pods and now plans to acquire pods to support the entire F-16 Block 50/52 fleet.[82]

HTS configurations are called "releases." Release 7 is the latest version.

Background[83]

A major difference between the F-16CM Wild Weasel and other F-16 variants is the HARM targeting system (HTS). "One hundred single-seat Block 50D aircraft were fitted with AN/ASQ-213 HARM targeting systems (HTS) to conduct suppression of enemy air defenses (SEAD) following the retirement of the F-4G Wild Weasel."[84] Understanding the capabilities of the F-16CM Wild Weasel begins with the HTS pod:

[82] See Jane's Aircraft Upgrades, from Jane's website, posted February 24, 2016.

[83] "F-16 Fighting Falcon multirole fighter," *Military Periscope*, accessed February 16, 2016, at https://www.militaryperiscope.com/weapons/aircraft/fighter/w0003152.html.

[84] From "F-16 Fighting Falcon multirole fighter," *Military Periscope*, accessed February 16, 2016, at https://www.militaryperiscope.com/weapons/aircraft/fighter/w0003152.html.

> The HTS was installed under the starboard side of the air intake. HTS improves the accuracy of the AGM-88 HARM anti-radiation missile by providing the range and direction of enemy air defense radars. The HTS was considered significantly less effective at finding enemy radars than the F-4G was. The HTS could see radars only in a limited cone forward from the aircraft. The preprogrammed database of radar frequencies was considered limited and usually did not include "war reserve mode" frequencies that could be different from those used during a radar's normal operation.
>
> To address these limitations, the HTS-equipped F-16s usually operate in conjunction with Air Force RC-135 Rivet Joint electronic reconnaissance aircraft and Navy EA-6B Prowler electronic warfare aircraft. For a time, while the RC-135 was being fitted with the IDM, it could only transmit voice instructions to the F-16.
>
> As a long-term solution, a limited number of F-16s were fitted with a multifunction information distribution system (MIDS) data link to provide a more robust link and allow targeting inflow from assets other than Rivet Joint.[85]

First Block 50D/52D was delivered to the Air Force on May 7, 1993. F-16 Block 50s were first designated F-16CJs. Initial operational capability with the HTS was reached in September 1994. Aircraft were later upgraded under Common Configuration Implementation Program (CCIP) and are now known as F-16CM/DM after this modernization. Both Block 40 and Block 50 upgraded under CCIP are designated "CM," but only the Block 50 performs SEAD.

Active Duty F-16 Block 50 "Wild Weasels" are flown by the 20th Fighter Wing, Shaw AFB, South Carolina; the 52nd Fighter Wing, Spangdahlem Air Base (AB), Germany; and the 35th Fighter Wing, Misawa AB, Japan. F-16 "Wild Weasels" are also flown by the Air National Guard's 169th Fighter Wing, McEntire Joint National Guard Base, South Carolina, and the 148th Fighter Wing, Duluth Air National Guard Base, Minnesota.

F-16CM Block 50 Sustainment and Modernization Efforts

The F-16 Block 50 "Wild Weasel" is sustained as part of the larger F-16 program, and as such most of the funding for sustainment and modernization is specifically allocated for the overall F-16 fleet. The specific F-16 "Wild Weasel" EW/SEAD sustainment and modernization initiatives focus on the HTS.

There are no further procurements of F-16 aircraft, as the Air Force is to begin retiring them once the F-35A Lightning II is fielded. The Air Force plans on using the capabilities of the F-35 to fulfill the SEAD mission in the long term.[86]

HARM Targeting System (HTS)

As previously mentioned, the primary modernization project for the F-16CM Wild Weasel is the HTS pod, as other aircraft upgrades or sustainment programs fall under the overall F-16 program. The *Manned Destructive Suppression (MDS)* program funds the development, procurement, and sustainment of the Air Force's SEAD and Destruction of Enemy Air Defenses (DEAD) capabilities. The upgrade is designed to achieve greater technological capability against enemy air defenses and to further reduce the time between target identification and destruction.

[85] Ibid.

[86] Author's interview with U.S. Air Force F-16 "Wild Weasel" pilot and Headquarters Air Force staff officer assigned as representative to the F-35 Joint Program Office (JPO) team.

The F-16 HARM Targeting System (HTS) is currently the only programmed reactive SEAD capability and enables targeting the HARM missile in its most lethal "range known" mode. With the introduction of HTS Revision 7 (HTS R7) in 2007, the AN/ASQ-213 Pod now has a precision geo-location capability to target Precision Guided Munitions (PGMs) to destroy fixed and mobile enemy air defense elements. Additionally, by relocating the AN/ASQ-213 HTS R7 Pod to the aircraft's left inlet hard point, the F-16 can simultaneously carry the HTS R7 Pod and an Advanced Targeting Pod (ATP). HTS R7 fielding is complete and represents the Air Force's near-term solution for reactive time critical targeting for SEAD until this mission can be transferred to F-35 or a yet to be defined system. HTS R7 derived precision targeting data can be provided to all Joint Forces via Link-16. This effort continues preplanned product improvements (P3I) for the HTS and applies technologies similar to those demonstrated in the Advanced Tactical Targeting Technologies (AT3) program and HTS R7 development.[87]

[87] DOD FY2017 President's Budget Submission, for Air Force justification book for research, development, test, and evaluation accounts, Volume 3a, p. 403, at http://www.saffm.hq.af.mil/shared/media/document/AFD-160208-052.pdf.

Table 4. F-16CM and HARM Targeting Systems Sustainment and Modernization

Procurement Items	Prior Years	Total Cost FY2015	Total Cost FY2016	Total Cost FY2017	Total Cost FY2018	Total Cost FY2019	Total Cost FY2020	Total Cost FY2021	Cost to Complete	Total Cost
F-16 Initial Spares/Repair Parts[a]	—	.090	0.472	2.059	2.453	6.135	9.794	9.75	—	30.978
Total Procurement Items	**—**	**.090**	**.0472**	**2.059**	**2.453**	**6.135**	**9.794**	**9.75**	**—**	**30.978**
RDT&E Items	**Prior Years**	**Total Cost FY2015**	**Total Cost FY2016**	**Total Cost FY2017**	**Total Cost FY2018**	**Total Cost FY2019**	**Total Cost FY2020**	**Total Cost FY2021**	**Cost to Complete**	**Total Cost**
F-16 HARM Targeting System (HTS)	—	14.413	14.860	14.773	15.062	15.347	15.631	15.909	Continuing	Continuing
Total RDT&E Items	**—**	**14.413**	**14.860**	**14.773**	**15.062**	**15.347**	**15.631**	**15.909**	**Continuing**	**Continuing**

Source: Prepared by CRS based on justification books for Air Force procurement account and Air Force research, development, test, and evaluation accounts for FY2017 and prior years.

a. Includes spares/repair parts for the whole F-16 fleet, not just Block 50/52 "Wild Weasel" aircraft.

Issues for Congress

DOD, Air Force, Navy Priorities

Upgrading EW aircraft capabilities in the U.S. military has not been a high priority for the past decade, which some analysts attribute to a generally permissive air defense environment resulting in a lower immediate need for EW use during that time. The opinion of some EW experts is that "the Defense Department doesn't have a strategy for what to do about electronic warfare ... we have lots of scattered good ideas and underutilized innovations, with potentially revolutionary round pegs being forced into the square holes of outdated doctrine and bureaucracies."[88] In addition, funding for EW has decreased in the past few years.

Recently, however, in light of broad agreement among defense planners regarding new threats, DOD has taken a renewed interest in Electronic Warfare. In March 2015, DOD created an EW Executive Committee to refocus the services on matters of EW strategy and operational capability. Deputy Defense Secretary Bob Work stated that he created the committee to help protect the United States' EW technical superiority, which is "diminishing rapidly."[89] In the memo that created the committee, Deputy Secretary Work wrote, "The [Defense Science Board] concluded that the DOD has lost focus on electronic warfare at the programmatic and strategic level and should recreate the mechanisms needed to develop EW strategies, synchronize programs, and advise the Secretary and Deputy Secretary of Defense on EW matters." The committee will be co-chaired by Pentagon acquisition chief Frank Kendall and the vice chairman of the Joint Chiefs of Staff.[90] The committee stood up in August 2015.[91] The military branches' acquisition executives are represented on the committee, as is the Office of the Under Secretary of Defense for Intelligence. At this writing, the committee has reportedly met a few times but intends to dive deeper into the EW field. The committee is to study EW testing, training, and prototyping, and make recommendations to the Deputy and Secretary of Defense.[92]

Total electronic warfare funding requested in the FY2017 RDT&E budget is $298 million, more than $100 million over the FY2016-enacted total of $184 million. The Navy hopes to receive the bulk of the EW RDT&E funding, with $183 million requested. The Army and Air Force have asked for $102.5 million and $12.5 million, respectively.[93]

Congress may wish to consider whether the Air Force and the Navy need to continue their current investment plans in light of the perceived need for future-generation EW capabilities to keep up

[88] "Electronic Warfare: We Have The Technology – But Not A Strategy," Breaking Defense, accessed January 19, 2016, at http://breakingdefense.com/2015/12/electronic-warfare-we-have-the-technology-but-not-a-strategy/. The referenced report is authored by Bryan Clark and Mark Gunzinger (2015): "Winning The Airwaves: Regaining America's Dominance In The Electromagnetic Spectrum," Center for Strategic and Budgetary Assessments website, accessed January 19, 2016, at http://csbaonline.org/publications/2015/12/winning-the-airwaves-sustaining-americas-advantage-in-the-electronic-spectrum/.

[89] "Electronic Warfare Executive Committee to Focus on Strategy, Acquisition," *USNI News*, accessed on October 9, 2015, at https://news.usni.org/2015/03/18/electronic-warfare-executive-committee-to-focus-on-strategy-acquisition.

[90] Ibid.

[91] "New committee looks to elevate electronic warfare," *Federal Computer Week (FCW)*, accessed February 10, 2016, at https://fcw.com/articles/2016/02/04/electronic-warfare-ndia.aspx.

[92] Ibid.

[93] "Funding for radar, electronic warfare, C4ISR, steady in DoD FY 2017 budget request," Military Embedded Systems, accessed March 23, 2016, at http://mil-embedded.com/4894-funding-for-radar-electronic-warfare-c4isr-steady-in-dod-fy-2017-budget-request/.

with developments by global challengers. Due to fiscal constraints and funding priorities, the Air Force divested itself of a large portion of its EW capability when it retired the EF-111 and the F-4G in the early 1990s. Since that time, the Navy—first with the Prowler and now the Growler—has been the primary service with stand-off jamming capability. In the area of airborne EW, the Navy continues to make considerable investments, more so than the Air Force.

An oversight issue for Congress may be whether Navy and Air Force EW platforms significantly overlap in capabilities and whether a single Service should be the main proponent of EW aircraft. Are combat EW operations likely to remain joint, multiservice efforts, or are those capabilities required by the Navy, Marine Corps, and the Air Force in a likely contingency?

The U.S. Navy concluded procurement of the EA-18G Growler fleet in FY2016, with the last aircraft scheduled to be delivered in spring 2017, for a total of 160 aircraft. The Navy's next focus will be on the Next Generation Jammer, as indicated by its recent $1 billion contract with Raytheon. The Marine Corps intends to operate its remaining 20 EA-6B Prowlers until 2019 and is looking for alternate solutions for organic EW requirements, to include UAV EW concepts.

The Air Force intends to maintain the F-16 Block 50 fleet viable until the F-35 Lightning II can perform the "Wild Weasel" mission, which would be possible with the "3F" software upgrade due to undergo Initial Operational Test and Evaluation (IOT&E) in the 2017-2018 timeframe. The EC-130H remains, in the meantime, a viable and much requested asset for Combatant Commanders, DOD, and the Air Force. Meanwhile, the Air Force is pursuing a transfer of the Compass Call capabilities onto a more efficient, better-performing aircraft. Proposed solutions include a business-jet type airplane, with intentions to purchase and maintain 10 primary aircraft. Due to the nature of evolving threats, the time required for development may be a driving factor in selecting a technology.

Potential for Shortfall in Airborne EW Capabilities

As the current Compass Call fleet continues to age, and development of replacements for some aircraft begins, a potential oversight issue for Congress is whether current DOD plans to sustain, modernize, and/or recapitalize the EC-130H Compass Call fleet may result in a shortfall in the nation's EW capabilities. Congress may continue to observe the current capabilities and where they potentially lag behind U.S. competitors. The proliferation of UAS has changed the EW environment considerably, and many EW and counter-EW capabilities could be added to unmanned platforms by allies and adversaries alike. Continuing RDT&E on future capabilities, such as the Next Generation Jammer (NGJ), is seen by DOD to be critical in ensuring that airborne EW systems operate effectively against adversaries who are developing advance jamming and countermeasures to thwart U.S. capabilities.

In February 2016, Members introduced new legislation aimed at boosting the Pentagon's electronic warfare efforts. The bill, called the Electronic Warfare Capabilities Enhancement Act (S.2486), comes a year after the creation of the previously mentioned Electronic Warfare Executive Committee. The bill would require the committee to provide Congress with a strategic plan for enhancing its electronic warfare capabilities, by encouraging cross-service cooperation, streamlining acquisitions, and improving training and advancing offensive capabilities.[94]

[94] S.2486, §5. See the **Appendix** for the full text.

The bill warns of a "deficiency in electronic warfare that if left unfilled is likely to result in critical mission failure, the loss of life, property destruction, or economic effects" and thus provides the Secretary of Defense with rapid acquisition authority for EW capabilities.[95]

Potential Adversary EW Capabilities

Congress, in its oversight responsibilities, might inquire whether DOD efforts are focused on overcoming near peer-competitors' advances in EW that could limit U.S. operations and capabilities and increase the risk of U.S. and Coalition forces.

In response to a U.S. advantage in air power over enemy IADS for the past 25 years, especially the ability to conduct the AEA mission from standoff ranges, competing nations have been exploring ways to modernize their IADS and regain an edge in this capability. Russia has not stopped modernizing its ground-based air defense systems since the end of the Cold War. After the collapse of the Soviet Union, one the few areas in which Russia was able to remain a global leader was in ground-based air defense radars and missiles.[96] Recently, Russia, China, North Korea, and to some extent Iran have been able to combine steady progress in radar and missile research with major advances in commercial signal processing technology, achieving major leaps in air defense capability that pose a credible challenge to Western air power. This increased capability enables these nations to provide an Anti-Access/Area Denial environment that limits U.S. military projection of power and adds risk to military operations.[97] Effective air defense and a wide array of radars are key elements of a successful A2/AD strategy.

One aspect of worldwide IADS modernization has been the development of more powerful and longer-range radars, as well as long-range, surface-to-air missiles (SAMs). Systems such as the Russian S-400 (SA-21) can detect and track large aircraft at ranges up to 570 km and engage them with missiles, such as the 40N6, at ranges up to 400 km. In 2015, China struck a deal with Russia to purchase four to six battalions of the SA-21 that will be a force multiplier and will enable China to strike aerial targets anywhere over Taiwan, Hanoi, Seoul, and deeper into the Yellow, East, and South China seas.[98] Systems such as these are designed to threaten stand-off ISR aircraft (RC-135 V/W Rivet Joint, E-8C Joint STARS, and P-8A Poseidon) and airborne early warning and control aircraft (E-3A AWACS Sentry and E-2D Hawkeye II) and push them back beyond the ranges of their sensors, where they cannot contribute much to the "sensor to shooter" network. This would also push aerial refueling tankers (KC-135 Stratotanker and KC-46A Pegasus) further out and reduce the ability of F-35 and F-18E/F fighter/strike aircraft to reach their targets.[99]

Implications of Modernization and New EW Efforts on Basing

Another potential oversight issue for Congress involves changes to legacy EW aircraft sustainment and modernization, and the procurement of new EW assets on any future rounds of

[95] S.2486, §3. See the **Appendix** for the full text.

[96] John Knowles, "Mission Profile: AEA for A2AD," *Journal Of Electronic Defense*, 38, no. 11: 26-36 (2015).

[97] For more information on foreign weapons sales, see CRS Report R44320, *Conventional Arms Transfers to Developing Nations, 2007-2014*.

[98] Wendell Minnick, "S-400 Strengthen China's Hand in the Skies," (2015) DefenseNews. Retrieved April 11, 2016, at http://www.defensenews.com/story/defense/air-space/strike/2015/04/18/china-taiwan-russia-s400-air-defense-adiz-east-china-sea-yellow-sea/25810495/.

[99] John Knowles, "Mission Profile: AEA for A2AD," *Journal Of Electronic Defense*, 38, no. 11: 26-36 (2015).

base realignment and closure (BRAC). Although DOD repeatedly included requests for a new BRAC effort in recent years' budget submissions, Congress has not authorized any such closures or realignments. In the continental United States, electronic attack aircraft are located at four locations: NAS Whidbey Island, Washington, for the EA-18G; MCAS Cherry Point, North Carolina, for the EA-6B; Shaw AFB, North Carolina, for the F-16 Block 50; and Davis-Monthan AFB, Arizona, for the EC-130H. There are two overseas locations for the E-3. Unlike other aircraft that are stationed at multiple bases in the United States and have been consolidated at one base in previous BRAC rounds, the legacy EW aircraft are already consolidated by aircraft type. Further consolidation by having multiple legacy C2ISR aircraft types at fewer locations is an option for consideration by future BRAC rounds, if they occur.

Appendix. Legislative Activity

FY2015 National Defense Authorization Act (P.L. 114-92)

DIVISION A – DEPARTMENT OF DEFENSE AUTHORIZATIONS

TITLE I – PROCUREMENT

Subtitle D – Air Force Programs

SEC. 143. PROHIBITION ON AVAILABILITY OF FUNDS FOR RETIREMENT OF EC–130H COMPASS CALL AIRCRAFT.

(a) PROHIBITION ON AVAILABILITY OF FUNDS FOR RETIREMENT.—None of the funds authorized to be appropriated by this Act or otherwise made available for fiscal year 2016 for the Air Force may be obligated or expended to retire, prepare to retire, or place in storage or on backup aircraft inventory status any EC–130H Compass Call aircraft.

(b) ADDITIONAL PROHIBITION ON RETIREMENT.—In addition to the prohibition in subsection (a), during the period preceding December 31, 2016, the Secretary of the Air Force may not retire, prepare to retire, or place in storage or on backup flying status any EC–130H Compass Call aircraft.

(c) REPORT ON RETIREMENT OF EC–130H COMPASS CALL AIRCRAFT.—Not later than September 30, 2016, the Secretary of the Air Force shall submit to the congressional defense committees a report that includes, at a minimum, the following:

(1) The rationale for the retirement of existing EC–130H Compass Call aircraft, including an operational analysis of the impact of such retirements on the warfighting requirements of the combatant commanders.

(2) Future needs analysis for the current EC–130H Compass Call aircraft electronic warfare mission set to include suppression of sophisticated enemy air defense systems, advanced radar jamming, avoiding radar detection, communications, sensing, satellite navigation, command and control, and battlefield awareness.

(3) A review of operating concepts for airborne electronic attack.

(4) An assessment of upgrades to the electronic warfare systems of EC–130H Compass Call aircraft, the costs of such upgrades, and expected upgrades through 2025, and the expected service life of EC–130H Compass Call aircraft.

(5) A review of the global proliferation of more sophisticated air defenses and advanced commercial digital electronic devices which counter the airborne electronic attack capabilities of the United States by state and non-state actors.

(6) An assessment of the ability of the current EC–130H Compass Call fleet to meet tasking requirements of the combatant commanders.

(7) A plan for how the Air Force will recapitalize the capability requirement of the EC–130H Compass Call mission in the future, whether through a replacement program or by integrating such capabilities onto an existing platform.

(8) If the plan under paragraph (7) includes integrating such capabilities onto an existing platform, an analysis that verifies that such platform has the space, weight, cooling, and power necessary to support the integration of the EC–130H Compass Call capability.

(9) Such other matters relating to the required mission capabilities and transition of the EC–130H Compass Call fleet as the Secretary considers appropriate.

(d) FORM.—The report under subsection (c) may be submitted in classified form, but shall also contain an unclassified executive summary and may contain an unclassified annex.

(e) NONDUPLICATION OF EFFORT.—If any information required in the report under subsection (c) has been included in another report or notification previously submitted to the congressional defense committees by law, the Secretary of the Air Force may provide a list of such reports and notifications at the time of submitting the report required under subsection (c) instead of including such information in such report.

TITLE XLI--PROCUREMENT

SEC. 4101. PROCUREMENT (In thousands of Dollars)

047 COMPASS CALL MODS	**68,415**	**97,115**
EC–130H Force Structure Restoration		**[28,700]**

Electronic Warfare Capabilities Enhancement Act of 2016 (S. 2486)

SEC. 2. FIELDING OF ELECTROMAGNETIC SPECTRUM WARFARE SYSTEMS AND ELECTRONIC WARFARE CAPABILITIES.

Funds authorized to be appropriated for electromagnetic spectrum warfare systems and electronic warfare may be used for the development and fielding of electromagnetic spectrum warfare systems and electronic warfare capabilities.

SEC. 3. INCLUSION OF ELECTRONIC WARFARE PROGRAMS IN THE RAPID ACQUISITION AUTHORITY PROGRAM.

(a) IN GENERAL.—Section 806(c)(1) of the Bob Stump National Defense Authorization Act for Fiscal Year 2003 (Public Law 107–314; 10 U.S.C. 2302 note) is amended by adding at the end the following new subparagraph:

"(D) (i) In the case of any supplies and associated support services that, as determined in writing by the Secretary of Defense without delegation, are urgently needed to eliminate a deficiency in electronic warfare that if left unfilled is likely to result in critical mission failure, the loss of life, property destruction, or economic effects, the Secretary may use the procedures developed under this section in order to accomplish the rapid acquisition and deployment of needed offensive or defensive electronic warfare capabilities, supplies, and associated support services.

"(ii) The Secretary of Defense shall ensure, to the extent practicable, that for the purposes of electronic warfare acquisition, the Department of Defense shall consider use of the following procedures:

"(I) The rapid acquisition authority provided under this section.

"(II) Use of other transactions authority provided under section 2371 of title 10, United States Code.

"(III) The acquisition of commercial items using simplified acquisition procedures.

"(IV) The authority for procurement for experimental purposes provided under section 2373 of title 10, United States Code.

"(iii) In this subparagraph, the term 'electronic warfare' means military action involving the use of electromagnetic and directed energy to control the electromagnetic spectrum or to attack the enemy, and includes electromagnetic spectrum warfare, which encompasses military communications and sensing operations that occur in the electromagnetic operational domain.".

(b) CONFORMING AMENDMENTS.—Section 2373 of title 10, United States Code, is amended—

(1) in subsection (a), by striking "and aeronautical supplies" and inserting ", aeronautical supplies, and electronic warfare"; and

(2) by adding at the end of the following new subsection:

"(c) ELECTRONIC WARFARE DEFINED.—The term 'electronic warfare' means military action involving the use of electromagnetic and directed energy to control the electromagnetic spectrum or to attack the enemy, and includes electromagnetic spectrum warfare, which encompasses military communications and sensing operations that occur in the electromagnetic operational domain.".

SEC. 4. AUTHORITY TO WAIVE THE JOINT REQUIREMENTS OVERSIGHT COUNCIL (JROC) FOR CERTAIN ELECTRONIC WARFARE PROGRAMS.

(a) ALTERNATE REVIEW.—The Secretary of Defense shall delegate to the Office of the Secretary of Defense's senior electronic warfare executive the authority to review and validate all Joint Capabilities Integration and Development System documents for electronic warfare acquisition programs notwithstanding section 181 of title 10, United States Code.

(b) JROC APPEAL.—The Joint Requirements Oversight Council may appeal to the Office of the Secretary of Defense to review any program through the normal Joint Capabilities Integration and Development System process.

SEC. 5. ELECTRONIC WARFARE EXECUTIVE COMMITTEE REPORTS TO CONGRESS.

(a) IN GENERAL.—Not later than 270 days after the date of the enactment of this Act, the Electronic Warfare Executive Committee shall submit to the congressional defense committees a strategic plan with measurable and timely objectives to achieve its mission according to the following metrics:

(1) Progress on intra-service ground and air interoperabilities.

(2) Progress in streamlining the requirements, acquisition, and budget process to further a rapid electronic warfare acquisition process.

(3) The efficiency and effectiveness of the acquisition process for priority electronic warfare items.

(4) The training methods and requirements of the military services for training in contested electronic warfare environments.

(5) Capability gaps with respect to near-peer adversaries identified pursuant to a capability gap assessment.

(6) A joint strategy on achieving near real-time system adaption to rapidly advancing modern digital electronics.

(7) Progress on increasing innovative electromagnetic spectrum warfighting methods and operational concepts that provide advantages within the electromagnetic spectrum operational domain.

(b) CONGRESSIONAL DEFENSE COMMITTEES DEFINED.—In this section, the term "congressional defense committees" means—

(1) the Committee on Armed Services and the Committee on Appropriations of the Senate; and

(2) the Committee on Armed Services and the Committee on Appropriations of the House of Representatives.

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