ARROYO CENTER

Defining an Approach for Future Close Air Support Capability

John Matsumura, John Gordon IV, Randall Steeb

Prepared for the United States Army

Approved for public release; distribution unlimited

For more information on this publication, visit www.rand.org/t/RR1233

Published by the RAND Corporation, Santa Monica, Calif.
© Copyright 2017 RAND Corporation

RAND® is a registered trademark.

Limited Print and Electronic Distribution Rights

This document and trademark(s) contained herein are protected by law. This representation of RAND intellectual property is provided for noncommercial use only. Unauthorized posting of this publication online is prohibited. Permission is given to duplicate this document for personal use only, as long as it is unaltered and complete. Permission is required from RAND to reproduce, or reuse in another form, any of its research documents for commercial use. For information on reprint and linking permissions, please visit www.rand.org/pubs/permissions.

The RAND Corporation is a research organization that develops solutions to public policy challenges to help make communities throughout the world safer and more secure, healthier and more prosperous. RAND is nonprofit, nonpartisan, and committed to the public interest.

RAND's publications do not necessarily reflect the opinions of its research clients and sponsors.

Support RAND

Make a tax-deductible charitable contribution at

www.rand.org/giving/contribute

www.rand.org

Preface

The Army Quadrennial Defense Review (QDR) Office asked the RAND Arroyo Center to conduct research on the close-support capabilities available in recent conflicts to help inform future planning decisions. Initially, the research the office requested was to include a broad set of close-support capabilities; however, this research subsequently refocused specifically on close air support (CAS) capabilities in recent conflict and the possible implications for the future.

The research provides an overview of the requirements process that led to existing CAS capabilities, contains information from warfighters, and includes the results of an assessment using state-of-the-art machine learning methods for coding to extract information on CAS capabilities that were provided to the Army over the past decade or so. This work should be of interest to a broad range of technologists, concept developers, materiel developers, and many others in the defense acquisition community.

The research on which this report was based was completed in July 2015, when the A-10 was still under debate.

This research was sponsored by the Army G-8, specifically the Army QDR Office, and was conducted within the RAND Arroyo Center's Forces and Logistics Program. RAND Arroyo Center, part of the RAND Corporation, is a federally funded research and development center sponsored by the United States Army.

The Project Unique Identification Code (PUIC) for the project that produced this document is HQD136504.

Contents

Figures and Table

Figures

Table

Summary

The Air Force recently proposed retiring the A-10 close air support (CAS) aircraft fleet, including canceling the service-life extension program that started in 2007, which was meant to extend the life of the aircraft by 20 years.[1] The Air Force has raised concerns about the A-10's survivability for many years. It asserts that the A-10 is no longer survivable on modern battlefields that include increasingly sophisticated and lethal air defenses and that multirole aircraft can perform the CAS mission effectively.[2] The Air Force plan for providing CAS after the A-10's retirement is to use current multirole aircraft, such as the F-16, and integrate the future multirole F-35A into the CAS role as it becomes available. By ending the program now, the Air Force leadership also expects to save the service approximately $3.7 billion.[3] Given the expected budget reductions, consolidation of Air Force CAS capabilities to save scarce defense dollars could be warranted if all the necessary capabilities remain available.

Cancellation of the A-10 program could, however, affect the Air Force's ability to provide a sufficient CAS for future operations. This could have a significant effect on the U.S. Army because it relies on the Air Force to provide most of its fixed-wing CAS. Since its fielding in the mid-1970s, the A-10 has been instrumental in providing CAS to ground forces in every major combat operation in which ground forces were deployed. And while other existing aircraft in the Air Force inventory can provide CAS, the kind of CAS that the A-10 provides involves desirable attributes that other multirole aircraft do not provide. Specifically, two characteristics that Army units highlighted in various after action reports from recent conflicts include the direct fire capability of the A-10's large cannon (GAU-8 30mm) and the morale and deterrent "show of force" effect that the presence of the aircraft over the battlefield creates. Relatively low-altitude, low-speed flight, for which the A-10 was specifically designed, enhances both characteristics.

It should be noted that the Army's recent experience with CAS was in relatively low-threat air defense environments—Iraq and Afghanistan from 2001 through 2015. The Army grew accustomed to CAS being performed at generally low altitudes (below roughly 10,000 ft), where friendly and enemy personnel were very much aware of the presence of aircraft performing this

[1] "US Air Force to Build 56 Additional A-10 Wings to Keep the Type Operating Through 2035," Deagle.com, September 4, 2013.

[2] U.S. General Accounting Office [now the Government Accountability Office], *Close Air Support: Status of the Air Force's Efforts to Replace the A-10 Aircraft*, Washington, D.C., GAO/NSIAD-88-211, September 1988. Also, for example, see the comments by Gen Michael Hostage, then–Air Combat Command commander, as reported in Chelsea Todaro, "A-10 Warthog No Longer Suitable for Middle East Combat, Air Force Leader Says," *National Defense*, July 29, 2014.

[3] Air Force Chief of Staff Gen. Mark Welsh, as reported in Colin Clark, "Air Force Chief Says Cutting A-10 Fleet Would Save $3.7 Billion; NDAA Blocks A-10 Retirement," Breaking Defense website, December 11, 2013.

mission, with associated morale effects on both sides. Meanwhile, the Air Force is considering the future operational environment, which in some situations could include much more challenging air defenses than aircraft have seen since combat operations began in 2001. While still recognizing the importance of the CAS mission to the Army, the U.S. Air Force is now thinking in terms of different aircraft and different tactics to perform this mission.

Recommendations

Given the importance of CAS to joint operations, future CAS requirements should be carefully reexamined. This reexamination should be similar to the process the Army and Air Force undertook in the late 1960s (see Section 2), in which the Army took on a significant role in defining key capabilities. The new assessment should directly address the needs of the affected services and their visions for future CAS. The planned CAS capabilities should be adopted if they meet the CAS requirements that emerge from this process and if a cost-based analysis validates the cost reductions the Air Force envisions.

However, if the plan does not meet the future CAS requirements or costs more than other alternatives that meet the CAS requirements, the current plan for providing CAS should be reconsidered, and a new plan should be developed.[4] This plan should be developed around achieving future requirements while avoiding key potential capability gaps. Here, alternative CAS concepts should be considered and examined, some of which we identify and discussed in this report. The larger analysis should compare near-, mid-, and far-term CAS alternatives to the A-10, including various fixed- and rotary-wing aircraft, both manned and unmanned, along with the cost implications. The analysis should also consider potential nonaircraft alternatives, such as ground-launched and loitering precision munitions.

Regardless of the outcome of the requirements reexamination process and the subsequent capabilities and cost-based analyses, we recommend fielding a viable replacement CAS capability, to minimize risk to ground forces, before eliminating the capability the A-10 provides. While the A-10 may not be the CAS solution for all combat environments, the decision to deploy it, as well as the decision to deploy ground forces, should be carefully addressed case by case.

[4] Ultimately, this may take on the form of a force-mix study that considers multiple joint scenarios and missions.

Acknowledgments

The authors would like to thank the Army War College and the many uniformed personnel—both Army and Air Force—who provided input to this research. COL Randall Cheeseborough at the Army War College in Carlisle Pennsylvania coordinated a meeting between RAND researchers and a number of students and faculty that proved to be very important to this research. We would also like to thank the sponsoring office, including Donald Tison and Timothy Muchmore in the Army G-8 office. At RAND, we acknowledge the considerable contributions of our colleagues Thomas Herbert, who conducted some of the modeling in this research, and James Pita, who developed the software used to extract information from significant activity reports. We also thank Phyllis Gilmore, who edited the report, and Laura Novacic, who formatted the draft. Finally, we thank our reviewers, Carl Rhodes and David Johnson, who worked through many versions of this document.

Abbreviations

CAS	close air support
COIN	counterinsurgency
ISIS	Islamic State of Iraq and Syria
MANPADS	man-portable air-defense systems
NATO	North Atlantic Treaty Organization
ODS	Operation Desert Storm
OEF	Operation Enduring Freedom
OIF	Operation Iraqi Freedom
QDR	Quadrennial Defense Review
RPG	rocket-propelled grenade
SAM	surface-to-air missile
SIGACT	significant activity
UAS	unmanned aerial systems
USAF	U.S. Air Force

1. Introduction

Definition of Close Air Support

Close air support (CAS) continues to be an important mission for the U.S. Army. Joint Publication 3-09.3 defines CAS as follows:

> Air action by fixed-wing and rotary-wing aircraft against hostile targets that are in close proximity to friendly forces, and requires detailed integration of each air mission with the fire and movement of those forces.[1]

CAS missions are notably different from other ground-attack missions, such as air interdiction and strike operations, which do not typically involve friendly forces in the vicinity of weapon release. In contrast, by definition, CAS involves dynamic interaction with ground forces and the flexibility to address a wide range of needs, including the ability to place ordnance with great precision in real time against enemies in close proximity to—or in direct contact with—U.S. forces. In some cases, in situ and real-time decisionmaking may be required to perform CAS, particularly when the ground battle is highly dynamic and when enemy and/or friendly positions are changing. Given that troops may be in contact with the enemy, small errors in target location and timing of weapon delivery can mean the difference between success and failure, and failure can include friendly ground force casualties. Thus, from the Army's perspective, the key attributes of a CAS capability are responsiveness, the ability to interact closely with ground forces that may be operating in very close proximity to or be directly engaged with the enemy, an ability to remain in the target area for extended periods as the ground force battle develops, and a means of delivering a variety of weapons both very accurately and in a timely manner.

While Navy and Marine Corps aircraft can, and have in the past, provided CAS for Army ground forces, the U.S. Air Force (USAF) holds the primary responsibility for providing CAS support to the Army. While the Air Force has used a wide variety of aircraft for the CAS mission, the A-10 ground-attack aircraft has provided much of the Air Force CAS capability for the past four decades. But the Air Force has said that the A-10 is no longer survivable for the CAS mission and will not be affordable as the Air Force modernizes and is therefore planning to decommission the A-10 fleet.[2]

---

[1] Joint Publication 3-09.3, *Close Air Support*, Washington, D.C.: Joint Staff, November 25, 2014.

[2] Congressional action has put a temporary restraint on U.S. Air Force divestment of the A-10 for years 2015 and 2016. Also, the fiscal year DoD budget request proposed delaying the A-10 retirement in order to maintain capacity in support of current operations. See U.S. Government Accountability Office, *Better Information Needed to Support Air Force A-10 and Other Future Divestment Decisions*, Washington, D.C., GAO-16-816, August 24, 2016.

Differing Perspectives on Close Air Support

The Army has received CAS since World War II. Importantly, the Army's recent experience with CAS has been in relatively low-threat air defense environments, such as Iraq and Afghanistan from 2001 through 2015. The Army grew accustomed to CAS being performed at generally low altitudes (below roughly 10,000 ft), where friendly and enemy personnel were very much aware of the presence of aircraft performing this mission, with associated effects on morale for both sides. This mode of CAS was very much to the Army's satisfaction and was generally similar to the way this mission had been performed since World War II.

Meanwhile, the Air Force is considering the future operational environment, which, in some situations, could include air defenses much more challenging than during the past 15 years of combat operations. While still recognizing the importance of the CAS mission to the Army, the USAF is now thinking in terms of different aircraft and different tactics to perform this mission. From the Air Force's perspective, two issues make retaining the A-10 problematic: cost and threat.

The USAF estimates that canceling the A-10 program would save approximately $3.7 billion over the next five years.[3] To conduct future CAS missions, the USAF intends to use its version of the Joint Strike Fighter, the F-35A Lightning II, as a replacement aircraft. Although many within both the Army and the USAF recognize the value of the A-10 as a dedicated CAS platform, some believe that eliminating this aircraft is now justifiable in the context of a shrinking defense budget. From the USAF's perspective, the A-10 represents a niche platform during a time when multirole platforms are needed to accomplish a broad range of missions affordably. While it is clear that the USAF has an interest in minimizing the cost of its fleet mix while maximizing capability across its mission set, its fleet mix decisions will directly affect U.S. ground forces, particularly the Army.

In addition to budget concerns, the Air Force is concerned that the A-10 is not survivable against many future threats. According to one now-retired commander of USAF's Air Combat Command,

> We talked specifically about the A-10, a weapon system I would dearly love to continue in the inventory because there are tactical problems out there that would be perfectly suited for the A-10. I have other ways to solve that tactical problem. It may not be as elegant as the A-10, but I can still get the job done, but that solution is usable in another level of conflict in which the A-10 is totally useless.[4]

---

[3] Air Force Chief of Staff Gen. Mark Welsh, as reported in Colin Clark, "Air Force Chief Says Cutting A-10 Fleet Would Save $3.7 Billion; NDAA Blocks A-10 Retirement," Breaking Defense website, December 11, 2013.

[4] Michael Hostage, "Air Combat Command's Challenge: Buy New or Modernize Older Aircraft," interview, *Air Force Times*, February 2, 2014.

Moreover, the USAF has stated that continuation of the A-10 jeopardizes the acquisition and the operations and sustainment resource base of the multirole F-35A.[5] Furthering the argument that the A-10 is a niche solution, Air Force commentators have noted that the A-10 will have survivability challenges in many or most envisioned future operational environments.

The most challenging threat that Air Force aircraft face today is radar-guided missiles. Some have relatively short ranges, such as the Russian SA-15 (roughly 12 km); others have much longer ranges, such as the Russian SA-20 (some models can engage aircraft over 200 km distant). During operations in Iraq and Afghanistan since 2001, the most common air defense threats have been small arms, rocket-propelled grenades (RPGs), some antiaircraft guns, and occasional man-portable air-defense systems (MANPADS).[6] It should be noted that, while few opponents have the financial means to arm themselves with operationally significant numbers of high-quality radar-guided air defense systems, even poorly armed countries and nonstate actors can often obtain at least some MANPADS and antiaircraft guns.

From the Army's perspective, CAS is one of the primary support functions that the USAF provides to Army combat operations. A benchmark 1948 policy agreement among the services, sometimes referred to as the Key West agreement, originally delineated this function.[7] This agreement integrated the Armed Forces into an "efficient team of land, naval, and air forces," and, within that arrangement, the USAF was given a primary mission to

> furnish close combat and logistical air support to the Army, to include air lift, support, and resupply of airborne operations, aerial photography, tactical reconnaissance, and interdiction of enemy land power and communications.[8]

Although some have questioned whether the Army's CAS requirements have changed since the Key West agreement was signed, our analysis of operations in Iraq and Afghanistan highlights and reinforces the continuing need for two critical CAS capabilities: (1) the ability to dynamically engage and reengage enemy threats that are in close proximity to friendly ground forces in all types of operations and threat environments and (2) the ability, during stability operations, such as in Iraq and Afghanistan, to provide a "show of force" to support relatively small and dispersed, remotely located ground units, such as combat outposts and patrols. For the Army, it is, therefore, important to understand how the decommissioning of the A-10 would affect the Air Forces' ability to maintain these specific CAS capabilities in the near and longer

---

[5] Hostage, 2014.

[6] Carlo Kopp, "Russian Air Defence Systems," Air Power Australia website, June 2011.

[7] The agreement is documented in James Forrestal, "Function of the Armed Forces and the Joint Chiefs of Staff," memorandum, April 21, 1948. President Harry S. Truman subsequently approved the agreement.

[8] Forrestal, 1948, p. 11.

terms. The Army and Air Force were engaged in high-level discussions about future CAS as this report was being finalized; the hope is that it can contribute to the ongoing discussions.[9]

Organization of This Report

While it takes much more than just an aircraft to deliver CAS, this report focuses on the aircraft platform. The following sections present a brief history of the requirements that resulted in the building of the A-10, a summary of CAS needs in recent conflicts, a brief description of future alternatives for providing CAS, and a discussion of the implications of this for the Army. The report concludes with recommendations for the Army and other services on an approach for defining future CAS capability.

---

[9] Colin Clark, "Air Force to Hold Close Air Support Summit; May Need New Weapon," Breaking Defense website, February 12, 2015.

2. Past Requirements for Close Air Support

Some perspective would be helpful for understanding current and future CAS requirements. How CAS should be provided has been a subject of ongoing discussion between the Army and the Air Force since before World War II. Over many decades, the Army leadership has held the position that CAS is a critical capability that the Air Force provides for the Army's ground units, and the Army has periodically provided input to the Air Force to ensure that aircraft design and tactics meet Army needs for CAS. The most recent major overhaul of CAS occurred in the 1970s, resulting in the A-10 platform.

Specifically, toward the end of the Vietnam War and with that combat experience in mind, the Army debated the Air Force about the requirements for CAS. Rather than relying on existing platforms, which had been based on long-range fighter-bombers, as the Air Force proposed, the Army leadership envisioned a different kind of platform that was more responsive to the CAS demands of units fighting in Vietnam. The ensuing cross-service discussions resulted in the development of requirements for a then future CAS-specific aircraft (Table 2.1). The notional A-X aircraft operational requirement documentation reflected these requirements.

The request for proposal the USAF issued in May 1970 specified an external payload of 16,000 lbs, maneuverable operations below 1,000 ft (with 1 nm visibility), a range of 250 nm, a two-hour loiter time within a target area, speeds between 350 and 400 kts, and an internally carried 30mm cannon that could fire at a rate of 4,000 rounds per minute.[1] In a competitive fly-off with the Northrop Grumman A-9, the Fairchild Republic A-10 met most of these requirements and was selected over the A-9. Interestingly, the Soviets adopted many of the features of the A-9 in their new CAS platform, the SU-25.

Table 2.1. Summary of Key Requirements for CAS

Key Characteristic	A-X Attributes for CAS	A-10 Specification
Large payload	16,000 lbs external weapon carriage	16,000 lbs external weapon carriage
Low-altitude maneuver	Operates below 1,000 ft	Maneuvers below 1,000 ft
Long range	250 nm	250 nm
Long loiter	2 hours on station	2 hours on station
Flyout speed	350–400 kts	350–400 kts
Heavy direct fire	30 mm cannon 4,000 rounds per minute	30 mm cannon 3,600 rounds per minute[a]

[a] 1,174-round standard drum.

[1] William Sweetman, *A-10: Thunderbolt II*, Arco Publishing, Inc., 1984.

A key design feature of the aircraft was the ability to survive hits from small-arms fire and light antiaircraft guns; this capability was necessitated by the assumption that an aircraft was likely to be hit by enemy fire while performing "low and slow" CAS missions. When the A-10 was designed, MANPADS were starting to proliferate—the Soviet-built SA-7 had been used in the last years of the Vietnam War—but the main threats to low-altitude aircraft in that era were antiaircraft artillery and small arms fire, particularly the heavy machine guns that had been responsible for downing large numbers of U.S. helicopters and fixed-wing aircraft in South Vietnam. In the early to mid-1970s, ground-attack aircraft had fewer options for precision-guided munitions than today and generally had to operate at a relatively low altitude to achieve accuracy with unguided weapons. Additionally, a large cannon was seen as a key weapon for a future CAS aircraft, and that weapon would have to be employed at low altitudes. Specific features to enhance the survivability of the A-10 included a titanium armor-plated cockpit, redundant flight control system separated by fuel tanks, a manual reversion mode for flight controls, foam-filled fuel tanks, ballistic foam void fillers, and a redundant primary structure to provide "get home" capability after a hit. *The Army–Air Force discussions in the early 1970s provide a good example of how two services can work together to develop a mutually acceptable weapon system to perform an important mission.*

While many of the design features adopted for the A-10 grew out of the CAS requirements of the Vietnam experience, the first A-10 aircraft was not delivered until 1976, after that war had ended. Subsequently, the A-10 was envisioned as a key interdiction and antiarmor platform in case of a Warsaw Pact attack against Western Europe. In that theater, the Soviet Union was capable of maintaining a sophisticated and integrated air defense system over the battlefield, a much more dangerous antiaircraft environment than the one in Vietnam. Due to the severity of Soviet air defenses, the concept for A-10 attacks included considerable amounts of Army artillery being used to suppress air defenses. Fortunately, war with the Warsaw Pact never occurred, and the Cold War ended without the A-10 being tested against a Soviet integrated air defense system. However, the A-10 has taken on a role in nearly every other major conflict involving U.S. ground forces since. It should be noted that the tactics the A-10 units use have varied depending on the threat environment. For example, while the aircraft is best known for low-altitude operations (which were normal in Iraq and Afghanistan), A-10s would operate and attack from higher altitudes in areas with more-severe threats, such as Kosovo in 1999.

3. Close Air Support in Recent Conflicts

Persian Gulf War (Desert Storm), 1991

Operation Desert Storm (ODS) in 1991 was the first major combat operation in which A-10s were actually employed, and they were used in both CAS and air interdiction roles.[1] Most of the 43 days of ODS involved preparation of the battlefield for the ground combat phase. During this phase, A-10s were frequently assigned to conduct air interdiction missions against enemy armor, artillery positions, and air defenses. The ground combat phase of ODS lasted less than five days and, due to the relatively low air defense threat, CAS aircraft operating at low altitudes were utilized to support advancing ground troops.

In all, A-10s were credited with destroying 987 tanks; 926 artillery pieces; and 1,355 combat vehicles during the conflict.[2] While the 144 A-10s deployed for the operation flew about 30 percent of the Air Force's combat missions, they were credited with over 50 percent of the total amount of Iraqi military equipment destroyed by air attacks.[3] While A-10s were performing CAS and relatively short-ranged strike missions into the Iraqi ground force array, other aircraft (both fighters and bombers) were used to strike targets deeper in Iraq, such as airfields, command centers, and logistics targets. Of the 8,000 sorties conducted, a total of only five A-10s were lost to enemy fire during ODS.[4] One was lost to antiaircraft gunfire and the other four to infrared-guided surface-to-air missiles (SAMs) of various types.[5] Even though relatively few were lost, 20 percent of the A-10s committed during the conflict sustained significant battle damage but demonstrated an ability to continue flying and return to base despite the damage.[6] During ODS, A-10s varied their tactics depending on the threat situation. A-10s would often fly

[1] The A-10 entered USAF service in the mid-1970s, shortly after the end of the Vietnam War, and was initially deployed to Europe in the last years of the Cold War, where its antiarmor capability could be put to good effect in case of a Soviet attack against the North Atlantic Treaty Organization (NATO). The European-based A-10s were earmarked for both CAS and relatively short-distance attacks inside enemy territory, a mission then known as battlefield air interdiction.

[2] These numbers are still being contested, but they give some sense of magnitude of contribution ("Air Force Fact Sheets: Airpower in Operation Desert Storm," About.com, undated).

[3] Other aircraft types were involved in combat missions beyond attacking Iraqi ground equipment, such as disrupting command and control and maintaining air superiority.

[4] A total of 32 fixed-wing aircraft of other types were shot down during the Gulf War. (General Accounting Office [now the Government Accountability Office], *Operation Desert Storm: Evaluation of the Air Campaign*, Washington, D.C., GAO/NSIAD-97-134, June 1997, p. 94.) There was also one noncombat loss.

[5] Direct comparisons of A-10 losses in ODS with the other 34 U.S. losses of fixed-wing aircraft during that conflict is impossible because of the differing operational profiles. (Robin J. Lee, "Coalition Fixed-Wing Combat Aircraft Attrition in Desert Storm," Estimative Error Probable website, undated.)

[6] Alfred Price, "To War in a Warthog," *Air Force Magazine*, August 1993.

to the target area above 10,000 ft to avoid the worst of the low-altitude threat (small arms, antiaircraft guns, and most MANPADS), descend to lower altitudes to make their actual attack runs, then climb back to safer levels after engaging their targets.

Operation Allied Force, 1999

A-10s were also employed in Operation Allied Force, the 1999 NATO air campaign against Yugoslavia. Of the 517 NATO aircraft (mostly U.S.) employed in that operation, 40 were A-10s. Because of the severity of the low-altitude threat inside Kosovo and a general NATO lack of willingness to take losses in that operation, fixed-wing aircraft generally operated above 10,000 ft. Therefore, most A-10 missions were conducted at medium altitudes, where the aircraft engaged targets with standoff weapons, such as the AGM-65D Maverick missile. However, A-10s still employed their 30mm cannons, descending below 10,000 ft to make their actual attack runs once a target had been identified. When allowed to operate at lower altitudes at night, they used their cannons even more often.[7] Two NATO fixed-wing aircraft were lost in Operation Allied Force, one F-16 and one F-117.[8]

Operations Enduring Freedom and Iraqi Freedom, 2001–2013

In more recent years, the A-10 has been primarily used in irregular warfare (e.g., counterinsurgency [COIN] and counterterrorism), against relatively poorly armed opponents (e.g., Iraq in 2003). More specifically, the A-10 was used in the intense major combat phases of recent operations and in the lower-intensity irregular warfare phases. During the major combat operations phase of Operation Iraqi Freedom (OIF) (March 20 to April 10, 2003), the CAS capacity of the A-10 was employed using CAS attack profiles similar to those for ODS and Kosovo—flying into the target area generally above 10,000 ft, but quickly descending to lower altitudes to engage targets. One A-10 was lost, apparently due to a European-made Iraqi *Roland* SAM.[9] CAS missions continued into the succeeding COIN phase of OIF, and A-10s were used extensively, but the need for CAS in Iraq had declined significantly by 2010.[10]

In Operation Enduring Freedom (OEF), the initial operations to topple the Taliban in Afghanistan lasted roughly two months (October–December 2001), but the United States has been involved in "lower-intensity" COIN operations in that country for more than 14 years as of

---

[7] Christopher E. Haave, and Phil M. Haun, eds., *A-10s Over Kosovo,* Maxwell Air Force Base, Ala.: Air University Press, 2003, pp. xv–xviii, 12–14, 24–30, 59.

[8] Martin Andrew, "Revisiting the Lessons of Operation Allied Force," Air Power Australia website, June 14, 2009.

[9] Derived from Army War College interviews, conducted in 2013.

[10] By this point, only one-quarter as many CAS missions were flown as in Afghanistan. (Anthony Cordesman and Marrisa Allison, "The U.S. Air War in Iraq, Afghanistan, and Pakistan," Washington, D.C.: Center for Strategic and International Studies, October 14, 2010.)

this writing. Operations in Afghanistan have presented many challenges because of the country's wide geographic area, mixture of major combat operations and stability missions, and small concentrations of mostly dismounted targets. The battles there have included offensive operations against enemy units; close-support missions protecting troops, bases, and routes under attack; and escort of casualty evacuation flights.

Detailed analyses of data from the 12-year war in Afghanistan highlight trends in the use of the A-10. We extracted statistics from almost 300,000 significant activities (SIGACTs) recorded from 2001 to 2012 and augmented them with data from published accounts of key battles and interviews with Army and Air Force veterans of the fighting in Afghanistan. These events were compiled using an automated data parser that could identify CAS operations. The first insight that emerged from the data was that A-10 missions in OEF (the first A-10 mission in Afghanistan was flown in March 2002) steadily increased over the years as ground commanders stepped up their requests for CAS, decreasing only somewhat as forces began to draw down in 2012. Figure 3.1 shows the progression of operations involving A-10s from 2002 to 2012.[11] The figure also pinpoints incidents that seem to have led to changes in enemy and friendly activity, such as elections, the surge, and the drawdown.

Additional analysis suggests that A-10s used their 30mm GAU-8 cannon much more frequently than they dropped bombs, typically guided bomb units. RAND interviewed over a dozen Army and several Air Force senior officers who fought in Iraq and Afghanistan, mostly during the lengthy COIN phases. From these interviews, the use of the direct fire cannon was preferred over guided bombs in some instances because of the former's higher accuracy and lower latency.[12] Some interviewees, however, noted that, in some cases, fighters faster than the A-10 (such as the F-15 or F-16) could arrive in the engagement area more quickly; they also noted that the A-10 could usually respond to requests for support more quickly than helicopters because it is faster than rotary-wing aircraft.

Comparing the activity of A-10s to that of other CAS aircraft reveals some notable differences.[13] From a normalized coding of the SIGACTs, A-10 flew approximately one-half of all the CAS missions shown in Figure 3.2 despite representing a small fraction of the total aircraft in theater. This suggests that other aircraft performed multiple roles, beyond CAS, assuming sortie generation rates were similar across aircraft. In the CAS missions, the reports on

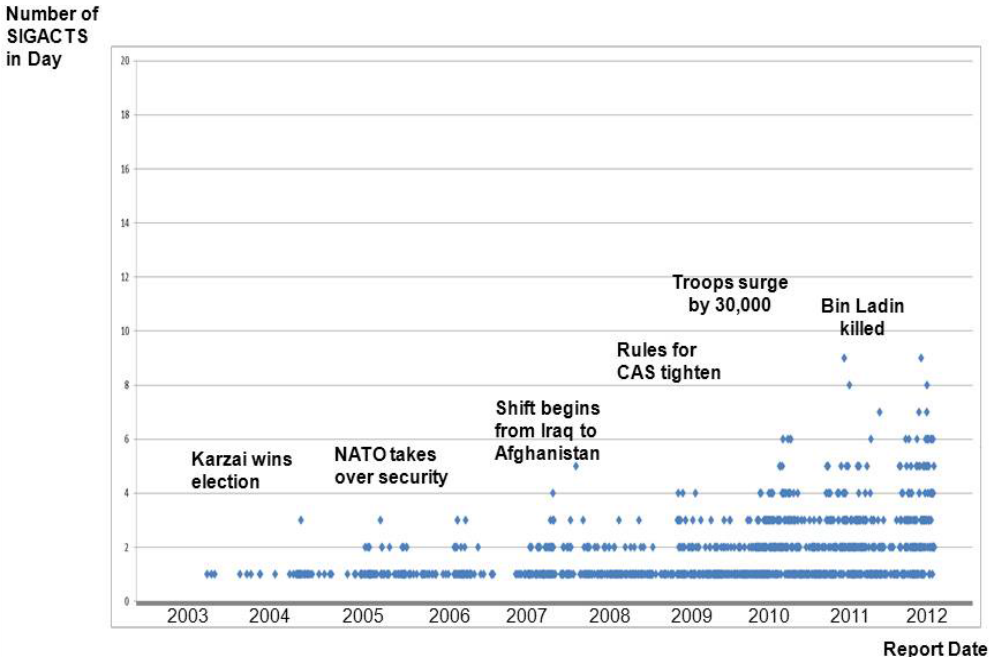
---

[11] These numbers included all references to A-10s in the reports, including engagements, shows of force, and calls for support.

[12] During the interviews, ground commanders expressed a preference for the 30mm cannon over precision bombs because of the cannon's high accuracy (80 percent of rounds within a 20-ft radius at 4,000-ft range), because it was better able to hit moving targets than bombs were, and because the collateral damage was lower than with bombs. Interviewees were colonels and lieutenant colonels from the Army and Air Force. Some were students, others faculty at the time of the interviews. All were combat veterans of Iraq or Afghanistan, or both. Also see Federation of American Scientists, Military Analysis Network, "GAU-8 Avenger," webpage, January 16, 2000. Interviews conducted at the U.S. Army War College, October 2013.

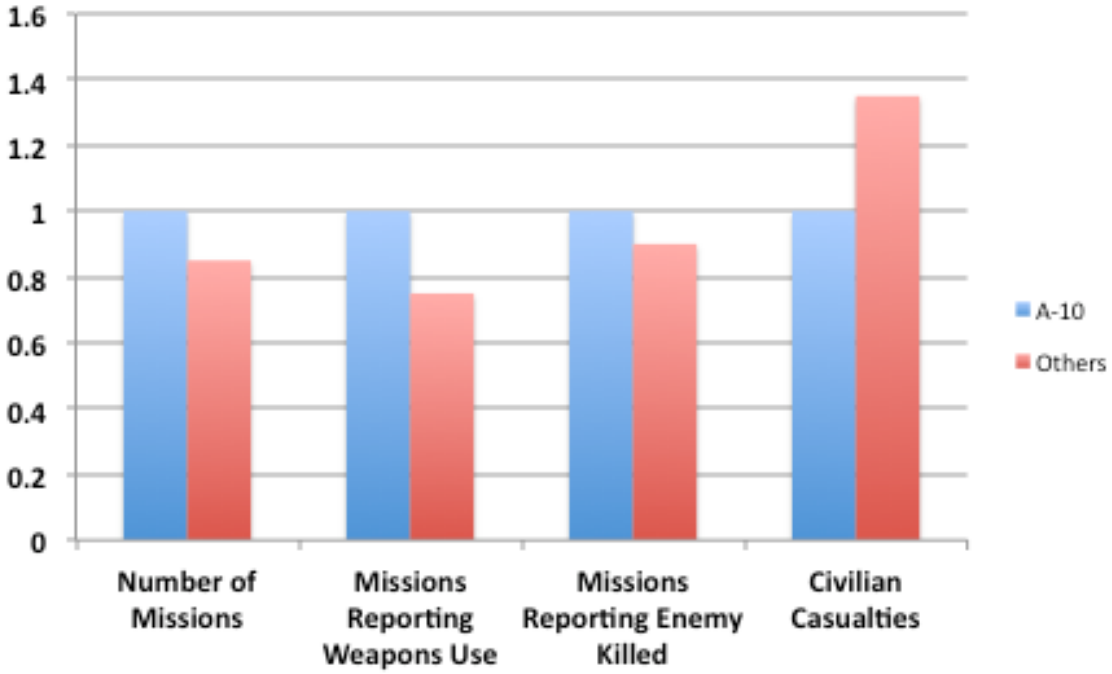
[13] Other aircraft in this assessment included F-16s and B-1s.

Figure 3.1. Steady Increase in SIGACTS Involving A-10s Through the Course of OEF



NOTE: Production generated from 18 to 24 A-10 airframes in theater at any given time.

Figure 3.2. Normalized Comparison of A-10 Activity with That of Other Fixed-Wing Platforms (Afghanistan 2002–2012)



SOURCE: Derived from coding of SIGACTS during this period.

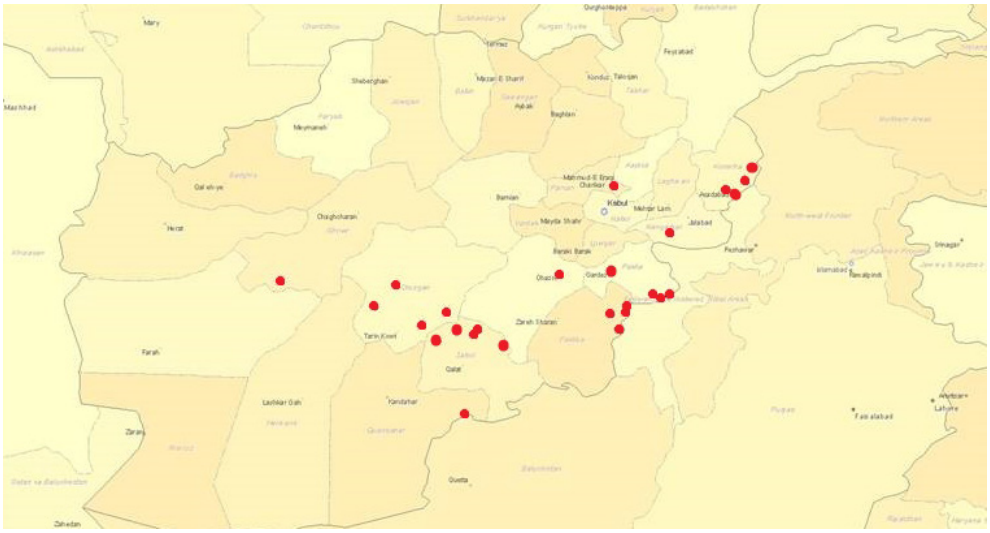
weapon use and enemy killed tended for other aircraft to be somewhat lower than those for the A-10.[14] Reports also suggest that civilian casualties were somewhat higher for other aircraft performing CAS. This can be explained by a number of factors that extend beyond the aircraft itself, including target location error, the latency and accuracy of the weapons used, and the scatter pattern of the warhead. As noted before, the A-10 often employed direct-fire 30mm cannon as its primary CAS weapon, while the other platforms typically employed guided bomb units.

Although approximately three to four times as many F-16 airframes as A-10s were in theater at any given time, the A-10 performed over one-half of all CAS missions, with F-16s averaging about 60 percent as many missions, on average. The data presented next elaborate on the location of CAS missions.

Examining the activities geographically, we found some other interesting dynamics with the various platforms. Early in the war (2003–2004), A-10s saw only sporadic action, covering a small number of areas (see Figure 3.3). This was due to the fact that the A-10 units departed Afghanistan in 2003 to support OIF. Once the A-10s returned to Afghanistan in 2005, however, the total area and density of A-10 missions rapidly increased (see Figure 3.4), covering all areas of the Kabul ring road and most of the bases in Afghanistan.

Figure 3.5 shows the same geographic area, but with A-10, F-16, and B-1 events highlighted in the corresponding different colors. The figure indicates that, even with lower speed and fewer platforms, A-10s seemed to cover more regions than other aircraft. B-1 strikes were concentrated around Bagram, while F-16s were employed mostly in the southern and western regions. It is

Figure 3.3. A-10 CAS Events Early in OEF (2003–2004)



[14] The F-16 (and F-15s, F-18s, F-22s, and F-35s) are fitted with 20mm cannons, but relatively few instances were seen of such weapons use due to its risk. See Richard Lewis, "The Art of Strafing," *Air Force Magazine*, July 2007.

Figure 3.4. A-10 Events in Afghanistan Increased in Both Number and Coverage Area over Time

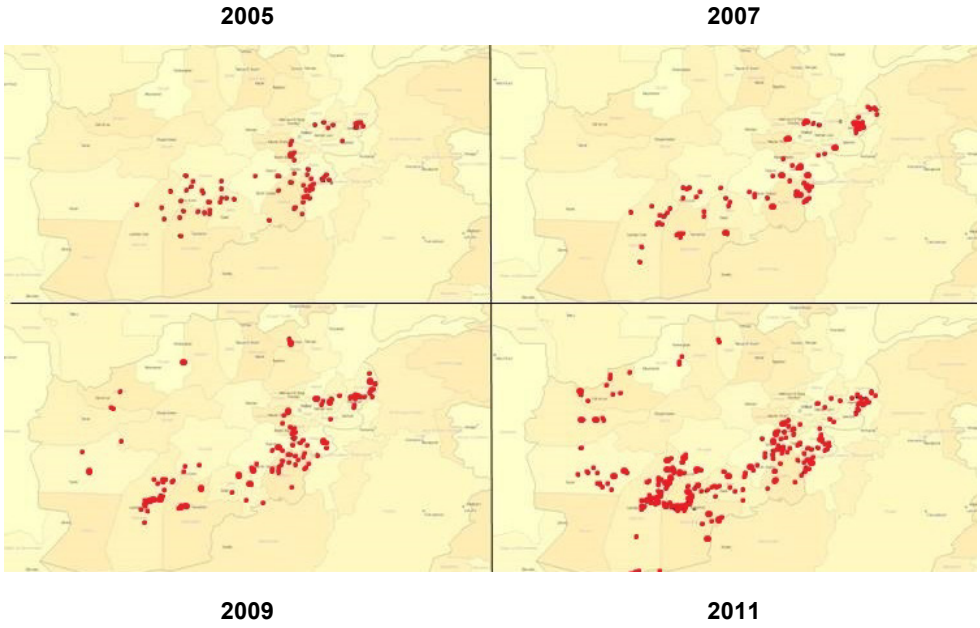
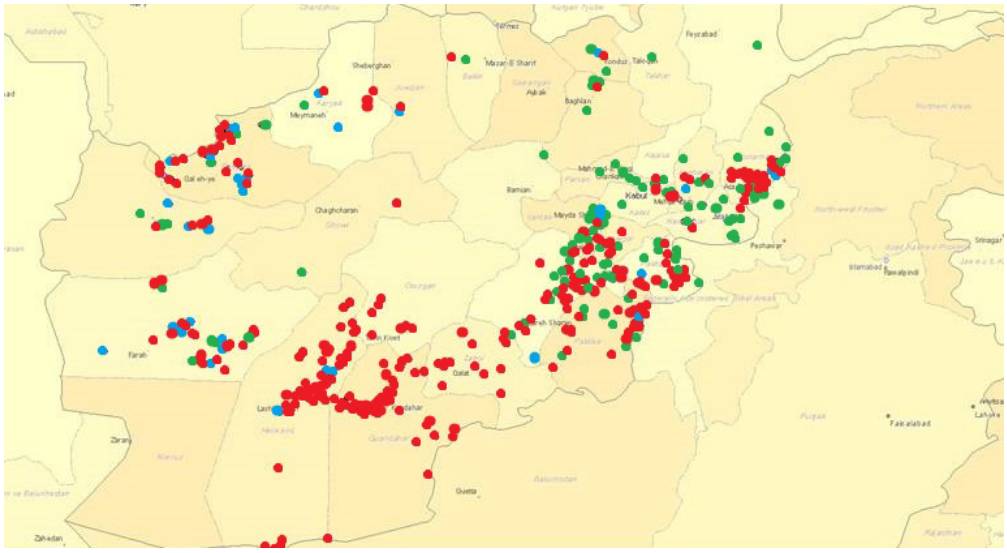


Figure 3.5. Location of Reports for A-10 (red), F-16 (blue), and B-1 (green) During 2011 in Afghanistan



unclear from the available data whether the greater geographic area of A-10 use was due to a preference for that platform in a CAS role over other aircraft or to other factors, such as aircraft basing. It should be noted that the data depicted in these figures reflects manned aircraft only, despite the fact that an increasing number of CAS missions were performed by unmanned aircraft as time passed.

The A-10 performed a significant number of missions during the major combat operations in both Iraq and Afghanistan; however, it is important to note that some fratricide incidents were reported. A-10s often performed CAS in very close proximity to friendly troops, including allied forces. The first fratricide incident took place on March 23, 2003, when two A-10s accidentally strafed a Marine Corps amphibious tractor unit in Nasiriyah; one Marine was killed, and 17 others wounded. On March 28, 2003, two U.S. A-10s accidentally attacked a British armored unit; one British soldier was killed, and five others were wounded.[15]

Only one A-10 was shot down during all of OIF and OEF. However, it should be noted that the air defense threat in both Iraq and Afghanistan was minimal. For roughly a decade before OIF began in March 2003, Operations Northern and Southern Watch had degraded the Iraqi air defense system. These capabilities were further degraded by the economic and military sanctions imposed on Iraq from 1991 to 2003. When combat started in Iraq in 2003, there was a radar SAM threat, particularly in the vicinity of Baghdad. Several hundred antiradiation missiles were used to suppress that threat, after which air operations became safer, including for the A-10s.[16]

Once major combat was over and the insurgency had begun, the U.S. military was fortunate that insurgent groups in Iraq did not have sophisticated air defense weapons, such as late-model MANPADS. Similarly, in Afghanistan, the Taliban in 2001 did not have meaningful air defenses, and the insurgents in 2002 through 2013 had even fewer air defense systems.[17] In a higher-threat environment, many of the A-10's tactics would place the aircraft at a high risk of being shot down. Indeed, against very high-quality air defenses, most current USAF and Navy aircraft would operate at considerable risk. A key question for decisionmakers who will decide on CAS tactics and platforms is whether future air defense threats will typically be more dangerous than in the ODS-OIF-OEF experience or whether air defenses (particularly at low altitude) will remain as manageable as they were in our most recent conflicts.

Combating the Islamic State of Iraq and Syria in Iraq, 2014–Present

Finally, A-10 missions have not ended with the drawdowns in Iraq and Afghanistan. In very recent action, A-10s have been deployed to fight Islamic State of Iraq and Syria (ISIS) in Iraq. Iraqi News reported that, in four strikes on the villages of Sultan Abdullah in Makhmour district, A-10s resulted in death and injury of dozens of ISIS militants.[18] Elements of the terrorist

---

[15] "U.S. Warplanes Hit Our Tank Convoy, Says Soldier," *Daily Mail* (London), January 30, 2007.

[16] T. Michael Moseley, "Operation IRAQI FREEDOM—By the Numbers," USCENTAF Assessment and Analysis Division, April 30, 2003.

[17] The air defense environment of the 1980s Afghanistan was different for the Soviets when they were operating in that theater. The United States provided Stinger missiles to the *mujahadeen* starting in 1986, and these proved effective against Soviet aircraft.

[18] Abdelhak Mamoun, "U.S. Wild Boar Aircraft Inspires Terror in ISIS Ranks in Mosul," Iraqi News website, January 15, 2015.

organization targeted the aircraft with four *Strela* (SA-7) missiles but were unable to hit the aircraft.[19] Active only since November 2014 against the militant state, A-10s have performed 11 percent of U.S. Air Force ground-attack sorties. Only the more-numerous F-16s, which have been targeting ISIS months longer, have a higher percentage of total attacks.[20]

Examining Survivability in These Conflicts

The A-10 was designed to have high survival rates from small-arms fire, RPGs, and many MANPADS threats. It is designed so that the crew compartment, ammunition, fuel tanks, and other key components are protected against 23mm rounds and 57mm fragments. In addition, the hydraulic systems, tails, and other components are configured redundantly and the hydraulics have manual backups in case of loss of hydraulic power. Finally, the A-10's high-bypass engines are cooled by air and shielded by tail booms, reducing target acquisition and lock-on probability from infrared missiles.[21] Most other fighters and the B-1 operate at higher altitudes to deliver guided weapons in the CAS mission.

Also of note, the A-10 has been more survivable than helicopters operating at low altitude. From 2003 to 2010, 12 Apache helicopters of various types were lost in Iraq to hostile fire.[22] During the COIN phase, the threat to aircraft in Iraq and Afghanistan was derived primarily from small arms, RPGs, occasional antiaircraft guns, and small numbers of MANPADS. What is clear from the available data is that, in recent conflicts, losses of fixed-wing aircraft have been considerably lower than for helicopters, even for aircraft that, like the A-10, occasionally descend to low altitudes to engage targets.

The MANPADS threat is important in considering the future of CAS. The latest versions of MANPADS—for example the Russian-made SA-18, *Igla*—pose a considerable threat to aircraft operating below 10,000 ft. In Iraq and Afghanistan, a variety of MANPADS were encountered, ranging from the old SA-7 to more modern SA-16s and 18s; fortunately, however, only small numbers of the more-modern MANPADS were apparently encountered. MANPADS will continue to proliferate in the future, and new capabilities will be fielded. As a result, a detailed threat analysis should be conducted in concert with a requirements and an effectiveness analysis.

Perhaps more important in terms of aircraft survivability is the issue of radar-guided air defenses. While less common than MANPADS and antiaircraft guns, modern radar-guided SAMs—whether short-range systems, such as the SA-15, or long-range ones, such as the SA-10 and 20—pose the greatest threat to modern combat aircraft. While these systems were rarely

---

[19] SA-7s are an older, even obsolete, shoulder-fired missile.

[20] Aaron Mehta, "A-10 Performing 11 Percent of Anti-ISIS Sorties," *Defense News*, January 19, 2015.

[21] David R. Jacques and Dennis D. Strouble, *A-10 Thunderbolt II (Warthog) Systems Engineering Case Study*, Wright-Patterson Air Force Base, Ohio: Air Force Center for Systems Engineering, 2010.

[22] Unfortunately, a direct comparison between losses of attack helicopters and of A-10s is not possible because the Army and Air Force track combat use differently.

encountered in Iraq and Afghanistan and while some future opponents will not have them, this threat would be present in many situations. How much of an influence this threat should have on future CAS tactics and the platforms themselves is an important issue.

4. Alternatives for Future Close Air Support

Although much of the current debate focuses on whether or not to retain the A-10 and, if so, for how long, other alternatives might be considered for meeting future CAS requirements. This section provides a qualitative description of the current CAS alternatives and suggests what characteristics of these alternatives a detailed assessment should consider. We also discuss two other, longer-term alternatives for providing CAS: conversion of the A-10 to a remotely piloted vehicle and development of a new, specialized unmanned CAS aircraft

The Status Quo: The A-10 Program

From the Army's perspective, a key advantage of retaining the A-10 is continuity. As discussed in the previous section, the aircraft has performed well in recent major combat operations (Iraq in 1991 and 2003) and low-intensity conflicts (Iraq and Afghanistan from 2002 through 2013). The Army is generally satisfied with the effectiveness of the aircraft and the capabilities it provides.

The main disadvantage of retaining the A-10 is that it is vulnerable to the current and future air defenses of many potential adversaries. The A-10's survivability features and emphasis on low-altitude attacks were originally designed in 1970s, when air defenses were less sophisticated and relied more heavily on small- and medium-caliber guns. While the number of A-10 losses has been low in recent conflicts, that will not likely be the case in the future as sophisticated MANPADS and radar-guided SAMs proliferate.

The A-10 is inexpensive relative to the multirole fighters that are the most likely alternatives. On average, the A-10 was acquired for approximately $20 million in 2014 dollars per aircraft.[1] This is a sunk cost—the Air Force has already paid for the platforms—so the cost to keep them in the inventory is largely related to ongoing sustainment and maintenance.[2] Nevertheless, the Air Force estimates that the elimination of future operation, maintenance, and sustainment costs for the A-10 will save approximately $3.7 billion between 2015 and 2019, with continuing savings beyond that.[3]

---

[1] Federation of American Scientists, "A-10/OA-10 Thunderbolt II," FAS Military Analysis Network website, November 2, 2016.

[2] For example, the wings on at least some of the A-10 fleet are being replaced through a service-life extension program. Boeing received a contract in 2007 to build and replace as many as 242 wing sets, which will extend the life of the A-10 fleet another 25 years, until about 2035 to 2040. The cost is estimated at less than $4 million per aircraft ("US Air Force to Build . . . ," 2013).

[3] Air Force Chief of Staff Gen. Mark Welsh, as reported in Clark, 2013.

Using the F-35A for Future Close Air Support

As noted, the Air Force plans to provide CAS in the future with the F-35A, but this means that CAS will be provided differently. Aircraft operating at higher altitudes are less visible, which could affect the morale of both friendly and enemy troops. Visibility works the other way, as well: Higher operating altitudes suggest that the ability of F-35 pilots may be less able to develop a detailed picture of an ongoing ground battle than A-10 pilots have been, which can be a concern when friendly troops are operating in close proximity to the enemy may. Future common operating picture technologies may, however, make up for this limitation. Moreover, operating at higher altitudes suggests that "gun runs" using the F-35A's 20mm cannon may not occur very often. This change could be significant because use of the A-10's 30mm cannon has been cited as the aircraft's main contribution to CAS missions in Afghanistan.

The F-35A has a faster dash speed than the A-10 and, in some situations, would be able to respond more rapidly to a request for ground support, particularly from troops far from an air base or fighter orbit. However, the lower loiter time of the F-35A means that the aircraft will spend less time on station than the A-10 can. Also, the F-35A would normally carry less ordnance than the A-10 does. These points mean that the F-35A brings less firepower to the ground battle than the A-10 and that, once the aircraft is on station, it takes longer for ordnance to impact targets. The F-35A is expected to use guided bombs—perhaps a small-diameter bomb to reduce collateral damage—for CAS. A weapon dropped from 20,000 ft takes approximately 1 min to reach the ground. In comparison, an A-10 loitering in the target area can hit a target with its 30mm cannon in a few seconds—if the threat environment is sufficiently permissive to allow the aircraft to be in the vicinity.

It is interesting to note that the Marine Corps will also be using its version of the F-35, the F-35B, for a variety of missions, including CAS. Today, the Marines rely on a combination of AV-8B Harriers and AH-1W Cobra attack helicopters for CAS.[4] The Marines will have many of the same issues as the Army and USAF when employing their F-35Bs in a CAS role. Thus, while the Marine Corps may occasionally use its F-35s for low-altitude attack, including strafing, it will probably have to use the F-35Bs from higher altitudes because of the vulnerability of the aircraft to low-altitude air defenses.

Relying on Other Manned Aircraft for Close Air Support

It should also be noted that the USAF has a variety of other aircraft capable of performing the CAS mission. As described earlier, F-15Es, F-16s, and B-1s have all been employed in a CAS role in recent conflicts. Additionally, the Air Force has a limited number of AC-130 gunships for ground attack, although that aircraft is usually employed to support special

[4] The Marines also have the F/A-18 C/D Hornets available for use as a CAS platform.

operations forces and is rarely used in daylight because of survivability concerns.[5] That said, in the absence of the A-10 and if the F-35A is considered as a less-than-optimal CAS platform, the Air Force could choose to focus other existing aircraft on the CAS mission. The differences between these aircraft and the A-10 in the CAS mission are similar to those discussed above for the F-35.

In addition, the Army could increase the use of its organic systems for the close support of its ground forces. Today, this could include direct fire (primarily from armored vehicles), indirect fire (field artillery and mortars), and helicopters.

Converting the A-10 to a Remotely Piloted Aircraft

One alternative to retiring the A-10 could be to convert the A-10 platform into a remotely piloted aircraft. Given that the airframe potentially has many more years of life (20 to 25 more years through the existing service-life extension program) and that the aircraft largely represents a sunk cost from an acquisition standpoint, a sensible alternative to outright cancellation of the program might be to convert the aircraft into unmanned aerial systems (UASs). Initial ballpark estimates suggest that the existing A-10 platform could be converted at a cost of $2 million to $5 million per aircraft (or 10 to 25 percent of the platform costs).[6]

This alternative could potentially leverage economy-of-scale effects from the Air Force's existing UAS infrastructure, including training, operations, maintenance, and sustainment. However, a disadvantage is that this option would likely decrease the effectiveness of the platform because pilots needing to make real-time decisions would be removed from the cockpit of the aircraft. In addition, the savings eliminating the A-10 fleet might accrue would disappear, and a new bill would be incurred for the conversion.

An issue that would have to be resolved if the A-10 was converted to an unmanned aircraft would be whether the platform's survivability would be improved or worsened. Even if the need for a pilot aboard the aircraft is eliminated, the MANPADS and radar-guided SAM threats would still have to be considered.

Developing a New Specialized Unmanned Platform for Close Air Support

Another alternative for providing CAS to the Army would be to develop a new UAS specifically tailored for CAS. In this alternative, the aircraft could be smaller than the A-10

---

[5] The AC-130 normally employs its 40mm and 105mm cannons from altitudes between 5,000 and 10,000 feet. This is one reason the aircraft tends to operate only at night and in relatively low-threat situations. (National Museum of the U.S. Air Force, "AC-130U," fact sheet, 2009.)

[6] The large disparity in cost estimates is due largely to the mix of sensor systems that would be required to provide the virtual situational awareness needed to conduct CAS missions. As an example of a manned to unmanned conversion, the F-4 fighter was modified into the QF-4 drone at a cost of $2.6 million per aircraft. (U.S. Air Force, "QF-4 Aerial Target," webpage, October 16, 2008.)

because it would be designed from the outset to be unmanned. In conceptualizing a new UAS for CAS, a range of design directions and choices would have to be examined. However, one of the attributes driving the platform would likely be the inclusion of a large-caliber, direct-fire weapon. Given the size and weight of the cannon, this platform would necessarily be large relative to most other UASs. However, another possibility might be to use small-caliber, direct-fire rockets (or missiles). In either case, these weapons would be integrated into the platform, where they would provide real-time (or near-real-time) direct-fire support to ground forces in close proximity to the enemy. This level of complexity may result in long development times for such systems, however, necessitating the need retain the A-10 or other manned platforms for the CAS mission for some extended period.[7]

[7] One example of large possible future CAS platforms is the Navy's Unmanned Carrier-Launched Surveillance and Strike aircraft. This complex system was recently delayed to the 2022–2023 time frame. (Mike McCarthy, "Fielding of UCLASS Delayed Two-Three Years, Navy says," Defense Daily Network, February 2, 2015.)

5. Conclusions: Implications for the Army of Decommissioning the A-10

CAS of ground forces continues to be an important mission in the context of joint force operations, an operational requirement that recent contingencies have validated. Air platforms performing CAS missions must contend with enemy fire and engage highly mobile and often elusive targets, over complex terrain (to include urban terrain), in austere operating areas, with limited support and intelligence, surveillance, and reconnaissance infrastructure. In many cases, time demands and complex engagement constraints are also part of the mission profile.

In the wake of the USAF's announcement that the A-10 ground-attack aircraft fleet would be retired, the Army asked the RAND Arroyo Center to examine the issues associated with the Air Force providing CAS from other aircraft platforms. In summary, we found the following:

- The A-10 conducts CAS differently from other aircraft. In Afghanistan, A-10 pilots used their 30mm GAU-8 cannons much more frequently than other weapons, including guided bombs. In contrast, the F-16 relied largely on guided bombs for CAS.[1] During interviews we conducted, many ground commanders expressed a preference for the 30mm cannon over precision bombs because the cannon is highly accurate (80 percent of rounds within a 20-ft radius at 4,000-ft range), is better able to hit moving targets than even precision bombs, and produces less collateral damage than bombs.[2] Also, many missions involved a show of force, in which aircraft flew low and slow over the U.S. ground forces to deter adversary activity.
- Recent U.S. conflicts pitted U.S. forces against unsophisticated air defenses—a combination of small arms, RPGs, and some shoulder-fired missiles. In these environments, the A-10 proved survivable. The A-10 is not state of the art, however, and will be more vulnerable against more-modern air defense capabilities, particularly the more-sophisticated MANPADS and radar-guided SAMs.
- The USAF has other options for performing the CAS mission, including F-15Es; F-16s; B-1s; and, soon, the F-35A. The Army could also increase the use of attack helicopters to support ground troops, although these are, like all aircraft, vulnerable to ground fire when operating at very low altitudes.
- The USAF estimates that canceling the A-10 program and replacing it with the F-35A (or other aircraft) for CAS could save approximately $3.7 billion over the next five years. From the USAF perspective, this also presents an opportunity to leverage a capable, multirole aircraft and gain significant operational efficiencies. However, other costs should be considered. Current estimates for the F-35A range from $85 million to

[1] The cannon on the F-16 is much smaller than that on the A-10, has fewer rounds, and is generally used for self-defense in air-to-air combat.

[2] See also Federation of American Scientists, 2000.

98 million per aircraft.[3] Since CAS missions often run concurrently with other USAF missions, using the F-35A instead of the A-10 for CAS may require more total aircraft in theater if the F-35A cannot provide the munitions or loiter time that the A-10 can. Similarly, it may be possible that fewer platforms will be available to perform CAS.

- Other alternatives for CAS exist, including converting the A-10 to a remotely piloted aircraft and developing a new specialized unmanned platform for CAS. These options might result in different levels of effectiveness and could be subject to long development times. However, an unmanned aircraft alternative could address Air Force concerns about pilot survivability while maintaining the ability to use a direct-fire cannon and, if need be, present a show of force at low altitude.
- **If the A-10 is decommissioned, alternative aircraft are likely to use different survivability tactics from those of the A-10, and this implies different CAS tactics.** The A-10 was designed to operate at low altitude and survive against small arms, RPGs, and early MANPADS. Since the A-10 entered service in the mid-1970s, many new air-to-ground engagement capabilities have emerged, particularly precision-guided munitions, and these weapons can hit point targets accurately, even when delivered from high altitudes. However, it takes time for ordnance released from a high altitude to arrive on target. This can potentially reduce the responsiveness of CAS against the highly dynamic and time-critical targets that would be expected when troops are in contact with the enemy. In addition, cannon fire against point targets is impractical from medium and high altitudes. As a result, calls for CAS would require greater deliberation to account for the increased time to target, and target choices would likely need to be more selective because engagement would be by single bomb drops as opposed to potential multiple gun passes. Perhaps most important, CAS would not be accompanied by a highly visible and intimidating aircraft presence.

Recommendations

Given the importance of CAS to joint operations, future CAS requirements should be carefully reexamined. This reexamination should be similar to the process the Army and Air Force undertook in the late 1960s in which the Army took on a significant role in defining key capabilities. The assessment should address the needs of the affected services and their visions for future CAS directly. The current plan for CAS capabilities should be adopted if it can meet the CAS requirements that emerge from this process and if a cost-based analysis validates the cost reductions the Air Force envisions.

However, if the plan does not meet future CAS requirements or would cost more than alternatives that provide similar CAS capabilities, the current plan for providing CAS should be reconsidered. A new plan would need to be developed that focuses on achieving future requirements and avoiding potential capability gaps.[4] Here, alternative CAS concepts should be examined, some of which we have already identified and discussed in this report. The larger

[3] Lockheed Martin, "How Much Does the F-35 Cost? Producing, Operating and Supporting a 5th Generation Fighter," webpage, 2015.

[4] Ultimately, this may take on the form of a force-mix study that considers multiple joint scenarios and missions.

analysis should compare near-, mid-, and far-term CAS alternatives to the A-10, including various fixed- and rotary-wing aircraft, both manned and unmanned, along with the cost implications. The analysis should also consider potential nonaircraft alternatives, such as ground-launched and loitering precision munitions.

Regardless of the outcome of the requirements reexamination process and the subsequent capabilities and cost-based analyses, we recommend fielding a viable replacement CAS capability *before* eliminating the capability the A-10 provides to minimize risk to ground forces. While the A-10 may not be the CAS solution for all combat environments, the decision to deploy it, as well as the decision to deploy ground forces, should be carefully addressed case by case.

Bibliography

"A-10/OA-10 Thunderbolt II," GlobalSecurity.org website, undated. As of November 14, 2014: http://www.globalsecurity.org/military/systems/aircraft/a-10.htm

"A-10 Warthog," AircraftCompare.com, 2009. As of November 14, 2014: http://www.aircraftcompare.com/helicopter-airplane/A-10-Warthog/8

"Afghanistan: 2 Americans Killed in Helicopter Crash," *New York Times*, April 9, 2013.

"Air Force Fact Sheets: Airpower in Operation Desert Storm," About.com, undated. As of October 15, 2015: http://usmilitary.about.com/library/milinfo/affacts/blairpowerinoperationdesertstorm.htm

Andrew, Martin, "Revisiting the Lessons of Operation Allied Force," Air Power Australia website, June 14, 2009. As of March 27, 2014: http://www.ausairpower.net/APA-2009-04.html

Bechhusen, Robert, "The Air Force's Awesome Attack Plane Has a Pretty Sad Replacement," War Is Boring website, August 12, 2013. As of November 14, 2014: https://medium.com/war-is-boring/adb2cef00361

Boechler, Kenn, "Going Tactical: A New Strike Aircraft for the Afghan Air Force," *Small Wars Journal*, October 1, 2013.

Callinan, Rory, "Decorated Diggers Tell a Different Truth About Storied Battle," *Sydney Morning Herald*, May 4, 2013.

Chivers, C. J., "A Closer Look at the Haqqani Anniversary Attack on American Afghan Outposts," *New York Times*, October 11, 2011.

CNN Wire Staff, "NATO Chopper Crashes in Western Afghanistan," CNN, May 24, 2011. As of October 16, 2015: http://www.cnn.com/2011/WORLD/asiapcf/05/24/afghanistan.chopper.crash/

Clark, Colin, "Air Force Chief Says Cutting A-10 Fleet Would Save $3.7 Billion; NDAA Blocks A-10 Retirement," Breaking Defense website, December 11, 2013. As of October 15, 2015: http://breakingdefense.com/2013/12/air-force-chief-says-cutting-a-10-fleet-would-save-3-7-billion/

———, "Air Force to Hold Close Air Support Summit; May Need New Weapon," Breaking Defense website, February 12, 2015. As of October 15, 2015: http://breakingdefense.com/2015/02/air-force-to-hold-close-air-support-summit-may-need-new-weapon/

Cordsman, Anthony, and Marrisa Allison, "The U.S. Air War in Iraq, Afghanistan, and Pakistan," Washington, D.C.: Center for Strategic and International Studies, October 14, 2010. As of October 15, 2015: http://csis.org/files/publication/100610_AfPakAir.War.Stats.pdf

Ditz, Jason, "NATO Kills at Least Eight Afghan Civilians in Fresh Air Strike," Antiwar.com, December 31, 2009. As of November 14, 2014: http://news.antiwar.com/2009/12/31/nato-kills-at-least-eight-afghan-civilians-in-helmand-air-strike/

Forrestal, James, "Function of the Armed Forces and the Joint Chiefs of Staff," memorandum, April 21, 1948. As of October 15, 2015: http://cgsc.cdmhost.com/cdm/singleitem/collection/p4013coll11/id/729/rec/1

Federation of American Scientists, "GAU-8 Avenger," FAS Military Analysis Network website, January 16, 2000. As of November 14, 2014: http://www.fas.org/man/dod-101/sys/ac/equip/gau-8.htm

———, "A-10/OA-10 Thunderbolt II," FAS Military Analysis Network website, November 2, 2016. As of November 9, 2016: http://fas.org/man/dod-101/sys/ac/a-10.htm

Freedberg, Sydney, "The Afghanistan Air War," *National Journal*, September 25, 2010.

Gall, Carlotta, "Evidence of Air Strike in Afghanistan Seems to Rebut U.S. Account," *New York Times*, September 8, 2008.

Gall, Carlotta, and Taimoor Shah, "Civilian Deaths Imperil Support for Afghan War," *New York Times*, May 6, 2009.

Gleason, Tim, "Attack Helicopters Losing Their Touch," *Defence Aviation*, September 23, 2011.

Grant, Greg, "Hey AF! Where's the Air Support?" DoD Buzz website, September 2009. As of November 7, 2016: http://www.dodbuzz.com/2009/09/17/hey-af-wheres-the-air-support/

Haave, Christopher E., and Phil M. Haun, eds., *A-10s Over Kosovo: The Victory of Airpower over a Fielded Army as Told by the Airmen Who Fought in Operation Allied Force,* Maxwell Air Force Base, Ala.: Air University Press, 2003.

Hostage, Michael, "Air Combat Command's Challenge: Buy New or Modernize Older Aircraft," interview, *Air Force Times*, February 2, 2014.

Jackson, Joseph A., "Moving Artillery Forward: A Concept for the Fight in Afghanistan," *Small Wars Journal*, 2010. As of November 1, 2016: http://smallwarsjournal.com/blog/journal/docs-temp/397-jackson.pdf

Jacques, David R., and Dennis D. Strouble, *A-10 Thunderbolt II (Warthog) Systems Engineering Case Study*, Wright-Patterson Air Force Base, Ohio: Air Force Center for Systems Engineering, 2010. As of November 14, 2014: http://www.lboro.ac.uk/media/wwwlboroacuk/content/systems-net/downloads/pdfs/A-10%20Thunderbolt%20II%20(Warthog)%20SYSTEMS%20ENGINEERING%20CASE%20STUDY.pdf

Joint Publication 3-09.3, *Close Air Support*, Washington, D.C.: Joint Staff, November 25, 2014.

Kopp, Carlo, "Russian Air Defense Systems," Air Power Australia website, June 2011. As of October 15, 2015: http://www.ausairpower.net/APA-Rus-SAM-AAA-Footage.html

Lamonthe, Dan, "Report: Army Denied Aid to Team Under Fire," *Marine Corps Times*, March 3, 2010.

Lee, Robin J., "Coalition Fixed-Wing Combat Aircraft Attrition in Desert Storm," Estimative Error Probable website, undated. As of October 15, 2015: http://www.rjlee.org/air/ds-aaloss/

Lewis, Richard, "The Art of Strafing," *Air Force Magazine*, July 2007.

Lockheed Martin, "How Much Does the F-35 Cost? Producing, Operating and Supporting a 5th Generation Fighter," webpage, 2015. As of October 15, 2015: http://www.f35.com/about/fast-facts/cost

Mamoun, Abdelhak, "U.S. Wild Boar Aircraft Inspires Terror in ISIS Ranks in Mosul," Iraqi News website, January 15, 2015. As of October 15, 2015: http://www.iraqinews.com/iraq-war/u-s-wild-boar-aircraft-inspires-terror-isis-ranks-mosul/

McCarthy, Mike, "Fielding of UCLASS Delayed Two-Three Years, Navy Says," Defense Daily Network, February 2, 2015. As of October 15, 2015: http://www.defensedaily.com/fielding-of-uclass-delayed-two-three-years-navy-says/

Mehta, Aaron, "If a Future A-10 Happens, Expect Minor Changes," *Defense News*, December 5, 2013. As of October 16, 2015: http://archive.defensenews.com/article/20131205/DEFREG02/312050013/If-Future-10-Happens-Expect-Minor-Changes

———, "A-10 Performing 11 Percent of Anti-ISIS Sorties," *Defense News*, January 19, 2015. As of October 15, 2015: http://www.defensenews.com/story/defense/2015/01/19/a10-strikes-isis-11-percent/21875911/

Moseley, T. Michael, "Operation IRAQI FREEDOM—By the Numbers," USCENTAF Assessment and Analysis Division, April 30, 2003. As of October 15, 2015:

http://www.globalsecurity.org/military/library/report/2003/uscentaf_oif_report_30apr2003.pdf

Mujumdar, Dave, "Navy Shifts Plans to Acquire a Tougher UCLASS," U.S. Naval Institute News website, November 12, 2013. As of October 16, 2015: http://news.usni.org/2013/11/12/navy-shifted-plans-acquire-tougher-uclass

National Museum of the U.S. Air Force, "AC-130U," fact sheet, 2009. As of November 1, 2016: http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104486/ac-130hu.aspx

Osborne, Kris, "Bill Blocks Air Force from Retiring A-10 Warthog," *DefenseTech*, December 13, 2013. As of November 1, 2016: http://www.defensetech.org/2013/12/13/bill-blocks-air-force-from-retiring-a-10-warthog/

Price, Alfred, "To War in a Warthog," *Air Force Magazine*, August 1993.

"Return of the Air Commandos: UAF Close Air Support for the 21st Century," Combat Reform website, December 14, 2009. As of November 14, 2014: http://www.combatreform.org/aircommandos.htm

Ricks, Thomas E., "The Battle of COP Keating: An Earwitness Account," *Foreign Policy*, October 10, 2009. As of November 14, 2014: http://ricks.foreignpolicy.com/posts/2009/10/10/the_battle_of_cop_keating_an_earwitness_account

Robertson, William G., ed., *In Contact! Case Studies from the Long War*, Vol. I, Fort Leavenworth, Kan.: Combat Studies Institute Press, 2006. As of November 14, 2014: http://www.cgsc.edu/carl/download/csipubs/robertson_contact.pdf

Rubin, Alissa J., "8 Young Afghans Killed in Strike, NATO Acknowledges," *New York Times*, February 15, 2012.

Smith, David, and Jonathan Bachman, "CAS Battle Drill," *Field Artillery*, September–October 2001.

Smith, Herschel, "Investigation of Marine Deaths in Kunar Province," *The Captain's Journal*, February 19, 2010. As of November 14, 2014: http://www.captainsjournal.com/2010/02/19/ar-15-6-investigation-of-marine-deaths-in-kunar-province/

Steeb, Randall, John Matsumura, Thomas J. Herbert, John Gordon, and William W. Horn, *Perspectives on the Battle of Wanat: Challenges Facing Small Unit Operations in Afghanistan*, Santa Monica, Calif.: RAND Corporation, OP-329/1-A, 2011. As of November 3, 2013: http://www.rand.org/pubs/occasional_papers/OP329z1

Sweetman, William, *A-10: Thunderbolt II*, Arco Publishing, Inc., 1984.

Tan, Michelle, "Aviation Brigade to Join in on Afghan Surge," *Army Times*, January 12, 2010.

Todaro, Chelsea, "A-10 Warthog No Longer Suitable for Middle East Combat, Air Force Leader Says," *National Defense*, July 29, 2014. As of October 15, 2015: http://www.nationaldefensemagazine.org/blog/lists/posts/post.aspx?ID=1570

"US Air Force to Build 56 Additional A-10 Wings to Keep the Type Operating Through 2035," Deagle.com, September 4, 2013. As of October 15, 2015: http://www.deagel.com/news/US-Air-Force-to-Build-56-Additional-A-10-Wings-to-Keep-the-Type-Operating-Through-2035_n000011868.aspx

U.S. Air Force, "QF-4 Aerial Target," webpage, October 16, 2008. As of November 1, 2016: http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104568/qf-4-drone.aspx

U.S. General Accounting Office [now the Government Accountability Office], *Close Air Support: Status of the Air Force's Efforts to Replace the A-10 Aircraft*, Washington, D.C., GAO/NSIAD-88-211, September 1988.

———, *Operation Desert Storm: Evaluation of the Air Campaign*, Washington, D.C., GAO/NSIAD-97-134, June 1997.

U.S. Government Accountability Office, *Better Information Needed to Support Air Force A-10 and Other Future Divestment Decisions*, Washington, D.C., GAO-16-816, August 24, 2016.

"U.S. Warplanes Hit Our Tank Convoy, Says Soldier," *Daily Mail* (London), January 30, 2007.

Wafa, Abdul Waheed, and John F. Burns, "U.S. Airstrike Reported to Hit Afghan Wedding," *New York Times*, November 5, 2008.