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Needs, Effectiveness, and Gap Assessment for Key A-10C Missions

An Overview of Findings

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Summary

To comply with a congressional directive in the National Defense Authorization Act for fiscal year 2016 regarding the capabilities to replace the A-10C aircraft, RAND Project AIR FORCE analyzed a range of missions assigned to the A-10C aircraft: troops-in-contact/close air support (CAS), forward air controller (airborne) (FAC[A]), air interdiction, strike control and reconnaissance, and combat search and rescue support (CSAR). RAND analyzed the needs that this mission set might generate in the next five years and assessed existing and planned forces' effectiveness and capability gaps in performing those missions. RAND found that U.S. Air Force–programmed forces can effectively conduct these missions with few gaps when flying in air defense environments characteristic of current counterinsurgency operations. Certain gaps—in responsive CAS, FAC(A), and CSAR, for example—could widen if A-10Cs are removed from the force. With or without A-10Cs, the Air Force–programmed forces will be challenged to perform some missions in environments with more capable air defenses, unless changes are identified and made to tactics, equipment, and training.

Over the past few years, the U.S. Air Force (USAF) has attempted to implement a retirement plan for its 283 A-10C aircraft, whose primary mission is close air support (CAS). However, Congress has repeatedly prohibited the Air Force from retiring the A-10, leading to an impasse in which the A-10C fleet remains active and deployed overseas but only some of the aircraft have received a life extension and no funds have been allocated for future upgrades. The effectiveness of the A-10C has not been part of this debate; instead, the future ability of the aircraft to perform its missions, the utility of alternative approaches for accomplishing the A-10C's mission set, and USAF priorities for modernization have all become points of dispute.

NDAA DIRECTION

The National Defense Authorization Act (NDAA) for fiscal year 2016, Section 142, again contained language specifying that funds were not to be used to retire the A-10C. The legislation went on to direct that "The Secretary of the Air Force shall commission an appropriate entity outside the Department of Defense to conduct an assessment of the required capabilities or mission platform to replace the A-10 aircraft," with a report to be delivered by September 30, 2016. In May 2016, RAND Project AIR FORCE was funded by the U.S. Air Force to perform this independent assessment. The NDAA language specified that the analysis include five primary tasks:

1. Future needs analysis for the current A-10C aircraft mission set to include troops-in-contact/close air support, air interdiction (AI), strike control and reconnaissance (SCAR), and combat search and rescue (CSAR) support in both contested and uncontested battle environments. The [assessment] shall include each of the following:
   I. The ability to safely and effectively conduct troops-in-contact/danger close missions or missions in close proximity to civilians in the presence of the air defenses found with enemy ground maneuver units.
   II. The ability to effectively target and destroy moving, camouflaged, or dug-in troops, artillery, armor, and armored personnel carriers.
   III. The ability to engage, target, and destroy tanks and armored personnel carriers, including with respect to the carrying capacity of armor-piercing weaponry, including mounted cannons and missiles.
   IV. The ability to remain within visual range of friendly forces and targets to facilitate responsiveness to ground forces and minimize re-attack times.
   V. The ability to safely conduct close air support beneath low cloud ceilings and in reduced visibilities at low airspeeds in the presence of the air defenses found with enemy ground maneuver units.
   VI. The capability to enable the pilot and aircraft to survive attacks stemming from small arms, machine guns, man-portable air-defense systems, and lower caliber anti-aircraft artillery organic or attached to enemy ground forces and maneuver units.
   VII. The ability to communicate effectively with ground forces and downed pilots, including in communications jamming or satellite-denied environments.
   VIII. The ability to execute the missions described in subclauses (I), (II), (III), and (IV) in a GPS- or satellite-denied environment with or without sensors.
   IX. The ability to deliver multiple lethal firing passes and sustain long loiter endurance to support friendly forces throughout extended ground engagements.
   X. The ability to operate from unprepared dirt, grass, and narrow road runways and to generate high sortie rates under these austere conditions.
2. Identification and assessment of gaps in the ability of existing and programmed mission platforms in providing required capabilities to conduct missions specified in clause (1) in both contested and uncontested battle environments.
3. Assessment of operational effectiveness of existing and programmed mission platforms to conduct missions specified in clause (1) in both contested and uncontested battle environments.
4. Assessment of probability of likelihood of conducting missions requiring troops-in-contact/close air support operations specified in clause (1) in contested environments as compared to uncontested environments.
5. Any other matters the independent entity or the Secretary of the Air Force determines to be appropriate.

SCOPE OF RAND'S ANALYSIS

Tasks 2 and 3 require a focus on "existing and programmed" capabilities, which are considered to be within the five-year Fiscal Year Defense Plan. Therefore, we worked with the USAF to derive the following list of aircraft, sensors, and weapons that typically perform relevant mission sets and represent important classes of capability in the Combat Air Forces:

- A-10C (primary CAS)
- F-16C and F-15E (multirole fourth-generation fighters)
- F-35A (multirole fifth-generation fighter)[1]
- B-1B (bomber)
- MQ-9 (remotely piloted aircraft).

We examined USAF capabilities with and without the A-10C to determine the possible effects of its retirement on future capabilities. We did not assess the CAS-capable aircraft of other services here, such as Marine Corps AV-8Bs and Navy

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F/A-18s, Army AH-64 helicopters, or U.S. Special Operations Command–operated AC-130 gunships. Likewise, we limited the list of munitions considered to those in the USAF plan that are relevant to the NDAA-listed targets. These included laser- and GPS-guided 500-lb bombs, two variants of the 250-lb Small Diameter Bomb (SDB), guided rockets and missiles, larger munitions for interdiction missions, and the 20-, 25-, and 30-mm guns on the F-16/F-15E, F-35A, and A-10C, respectively.

Several potentially interesting areas of analysis—particularly gap mitigation, cost-effectiveness, and force structure—were not within the scope of the NDAA direction. Where gaps were identified, we did not attempt to analyze possible solutions, although we did attempt to highlight obvious and likely low-cost solutions, as well as capture ongoing USAF efforts in relevant mission areas. Including cost comparisons in analyses of this type would provide additional critical information to support decisionmaking. Although our capacity analysis considered mission needs, we did not attempt to examine campaign needs or the impacts of joint force, multidomain, combined arms employment that could provide insight into the total force structure size and mix required. Cost would be a critical part of force structure analyses as well, as the Air Force might achieve similar overall warfighting effectiveness at widely varying life-cycle costs. All three of these areas would make fertile ground for future research on the A-10C's mission set. Although we considered the use of space for communication and navigation, we did not consider intelligence, surveillance, and reconnaissance capabilities in space. Cyber risks and opportunities were also not part of this study.

WHAT ARE THE A-10C'S MISSIONS?

It is important to be clear that missions are not aircraft. Joint Publication 3-0 defines a mission as

> 1. The task, together with the purpose, that clearly indicates the action to be taken and the reason therefore. 2. In common usage, especially when applied to lower military units, a duty assigned to an individual or unit; a task. 3. The dispatching of one or more aircraft to accomplish one particular task.

The first step in our analysis involved describing the mission set by breaking down each mission into the roles played by the A-10C today and the various functions that would be necessary to successfully accomplish that mission in the future. As described in Task 1 of the NDAA, A-10C analysis should include troops-in-contact/CAS, AI, SCAR, and CSAR. Although our analysis focused primarily on the NDAA-defined missions, with the addition of forward air controller (airborne) (FAC[A]), this is not a complete list of the A-10C's mission set. The A-10C's Tactics, Techniques and Procedures manual states,

> The primary A-10 mission, close air support (CAS), is performed with a variety of forward firing, free-fall, and precision-guided munitions (PGM). Additionally, the A-10 can support a broad spectrum of other taskings such as combat search and rescue (CSAR), air interdiction (AI), armed reconnaissance (recce), suppression of enemy air defenses (SEAD), special operations forces (SOF) support, and countersea operations. All of these missions can be conducted in a low- or high-threat environment, day or night.[2]

We also note that Air Combat Command (ACC) directs A-10C units to train to be proficient in CAS, FAC(A), and CSAR as their primary missions, and to be familiar with Counter Fast Attack Craft/Fast Inshore Attack Craft and AI missions. Possible gaps in capability in missions not analyzed here should be considered in a broader analysis of the future USAF force structure.

CAS and AI are both "counterland" missions in USAF doctrine, defined as "Airpower operations against enemy land force capabilities to create effects that achieve joint force commander objectives" (U.S. Air Force, 2016). SCAR and FAC(A) missions are doctrinally treated as "derivative" counterland missions.[3] Note that we examined two separate tasks that better align with the A-10C mission set for SCAR: strike coordination, which has some attributes similar to FAC(A), and armed reconnaissance. We also highlight that a FAC(A)-qualified pilot can conduct SCAR but a SCAR pilot without the special training required for the FAC(A) qualification cannot conduct FAC(A) duties. Table 1 summarizes each mission and details important attributes of the mission set and key roles and tasks.

HOW DID WE DETERMINE MISSION EFFECTIVENESS AND NEEDS?

To capture all the NDAA-specified tasks and conditions under Task 1, we organized our study into several analytic efforts to calculate effectiveness and identify gaps in platforms and functional areas such as weapons, sensors, and communications. Across these analyses, we considered the effects of operational and environmental factors, such as weather, GPS and communication jamming, camouflage and concealment, target type, and ground controller capabilities. Since the mission functions almost always included target acquisition, communication, and weapon employment tasks that had to be performed while maintaining high survivability, our specific research areas were focused similarly.

Table 1. Characteristics of the NDAA Mission Set

Mission	Key Characteristics
Close air support	• Air action by fixed-wing and rotary-wing aircraft against hostile targets that are in close proximity to friendly forces; requires detailed integration of each air mission with the fire and movement of those forces • Flown under the control of a joint terminal air controller (JTAC) on the ground or an FAC(A) • Includes troops-in-contact situations, in which high responsiveness and low risk to friendly forces are required; simple presence can help shape the battle • Includes more-controlled circumstances in which responsiveness and fratricide risks are not so stressing • Wide range of possible target types
Air interdiction	• Action(s) to divert, disrupt, delay, or destroy the enemy's military surface capability before it can be used effectively against friendly forces or to otherwise achieve objectives • Can require autonomous locating of targets by aircraft and less coordination with land forces • May take place deeper in enemy territory and behind the forward line of own troops (FLOT), thus facing more advanced air defenses and longer ranges for aircraft and communications • Wide range of possible targets, perhaps in large numbers
Strike coordination and reconnaissance	• Strike coordination portion: Somewhat similar to FAC(A) in that the emphasis is not on strike but on understanding the ground situation, finding and identifying targets (and friendly forces), and communicating that knowledge and targeting information to CAS or AI aircraft • Armed reconnaissance portion: Missions flown for the primary purpose of locating and attacking targets of opportunity (i.e., enemy materiel, personnel, and facilities) in assigned general areas along assigned ground communication routes • Similar in many ways to AI, requiring fairly autonomous locating of targets; may involve greater coordination with ground forces if operating in support role • Must be able to mark targets with laser pointers or with less-lethal munitions
CSAR	• This mission can combine the difficult parts of the previous missions • "Sandy" roles include rescue mission commander (Sandy 1), FAC(A) (often Sandy 2), and rescue vehicle (RV) escort (RESCORT) (Sandy 3 and 4) • Unique need to securely communicate with isolated persons (IPs) • Training is central to executing diverse and complicated missions with little available planning time

Next, we examined available target acquisition options using the standoff levels determined in the previous step.

The NDAA directed analysis "in both contested and uncontested battle environments."[4] Thus, our initial research focused on possible survivability needs—specifically, the altitudes and standoff ranges necessary to achieve high levels of survivability against a variety of air defenses if they could not be destroyed or countered by other means.[5] We conducted detailed one-on-one modeling with U.S. Department of Defense (DoD) standard tools, where possible, and used intelligence assessments of capabilities for the remainder.[6] With this information, we created four "standoff levels" with increasing operating distances or overflight altitudes from threats to guide the other analyses. We did not assume that certain defense types would automatically lead to specific standoff needs but instead examined the effects of standoff, if required, on mission needs, effectiveness, and gaps.

Next, we examined available target acquisition options using the standoff levels determined in the previous step. Specifically, we examined sensor performance needs for area search and target identification in different missions, which we compared to the various sensors available, including the naked eye and use of binoculars. Another key output of this analysis was the target location errors (TLEs) generated by the various sensors. We relied on outputs from both of the previous tasks to examine the effectiveness of the planned munitions against our target set.

We considered mission needs for various environmental factors as well, including the four standoff levels, bad weather, moving targets, close friendly forces, GPS jamming, and poorly equipped or missing JTACs on the ground. We then used the suitability and effectiveness results to develop an overall picture of mission effectiveness using such information as munition loadouts, range and loiter times, sortie rates, and the ability of our selected aircraft types to operate from soft surfaces and lower-quality runways.

We also assessed communication needs and training levels. Several missions we examined require close coordination with ground forces, other aircraft, command-and-control nodes, and, potentially, IPs on the ground. For this reason, communication equipment can have a significant impact on mission effectiveness. Finally, because mission effectiveness is often determined more by the operators' level of training and skill than by their equipment, we conducted a brief examination of training levels across the various aircraft types, in terms of both required sorties and real-world training accomplished over the past few years.

HOW WELL DO USAF PROGRAM OF RECORD FORCES PERFORM THE MISSIONS?

We examined the mission performance of USAF platforms in the program of record for the 2022 time frame in the context of a range of possible air defense levels, from low to high.

Against Low Levels of Air Defense

Mission effectiveness depends on the ability of a platform to survive in the face of air defenses that have not been preemptively suppressed or destroyed. At the lowest level of threat, the most prevalent air defense systems that USAF aircraft face in operations in Syria, Iraq, and Afghanistan are simple machine guns and anti-aircraft artillery (AAA). An occasional man-portable air defense system (MANPADS) is encountered as well. Almost every fighting force possesses these weapons, and they are fired regularly at U.S. aircraft today. Despite this level of proliferation, the USAF has not lost a manned, fixed-wing aircraft to these weapons since 2003, largely thanks to robust airframes and improvements in weapons and sensors that permit avoidance of these threats while enabling effective strikes from higher altitudes and longer standoff ranges. Additionally, the successful developments of specialized tactics have minimized aircraft vulnerability and actively threaten these air defense systems. Meeting the minimum level of survivability to operate in the face of these systems requires minimizing exposure time with a survivable airframe, such as the A-10C, and effective countermeasures or sensors and weapons that can permit operations at least 10,000–20,000 ft away from the threat. Avoidance by overflight at altitudes above threat capabilities is often a preferred option, since these types of defenses can be very difficult to detect.

In analyzing the planned USAF fleet for gaps in effectiveness, we found few cases in which the planned force could

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not meet demands against lower levels of air defense. Facing unsuppressed smaller-caliber guns, against which essentially every platform, sensor, radio, and munition could be brought to bear, there were no major gaps. Solutions were available even for challenging situations, such as CAS targets 300 ft from friendly forces under low cloud cover; solutions included current guns, missiles, and guided rockets. Less traditional options were available as well, such as identifying the target's location with synthetic aperture radar (SAR) and striking with low-collateral-damage munitions. Sensors and communication systems were typically not a problem because of the short ranges involved.

Our worst-case capacity demands involved needing to service between 100 and 200 CAS targets per day in support of a division-level effort. A force of between 100 and 200 aircraft would be sufficient even if, conservatively, one-third of those aircraft could find and attack targets and if each attack killed two targets per sortie.[7] If sensor and weapon capabilities drop below these levels, or if multiple divisions require simultaneous support, additional aircraft would be needed to meet the demand.

In the CSAR mission, the U.S. joint personnel recovery capability, particularly the USAF "triad" of specialized helicopters, refuelers, and highly trained personnel, is effective when the range and the threat environment allow highly trained Sandy aircraft to coordinate and escort the rescue effort.

The other primary gap affects long-range operations if tankers are not available, but these cases are unlikely against all but the highest level of anti-access capabilities. Here, long-range bombers would provide the only option, and their munition choices—particularly for highly dynamic and close-proximity cases—would be limited or nonexistent. USAF aircraft that can operate from lower-quality airfields, such as the A-10C, MQ-9 and, to a lesser extent, the F-16, can also provide some robustness in this situation.

Against Medium Levels of Air Defense

Risk would be significantly higher if MANPADS that cannot be effectively countered with expendable flare technology proliferate. If advanced MANPADS proliferate, the choice will be between advanced but heavy and expensive countermeasures or consistently operating at a few miles of standoff—unfortunately placing the aircraft outside visual range to the target and placing the target out of reach of the aircraft's guns. In these cases, survivable airframes are not an option; larger-caliber guns and missile warheads are simply too powerful for armor to withstand. Note that in the CSAR mission, in which rescue vehicles (such as helicopters) are needed as well, simply having survivable escort aircraft is not sufficient. CSAR and AI missions, which are likely to take place deeper in adversary territory, are also more likely to encounter unlocated or unknown air defenses.

If MANPADS or shorter-range surface-to-air missiles (SAMs) with enemy ground forces cannot be suppressed or countered, and USAF aircraft are forced to operate from a few miles of standoff distance, we begin to see drops in effectiveness. Operations such as shows-of-force would not be possible. Since visual targeting is no longer an option, electro-optical and infrared (EO/IR) targeting systems are a critical capability to provide target identification, although they have their limits. For instance, it can take three minutes to detect vehicle-size targets in a visual search of a 5-nm^2 area, while a targeting pod can require 10–20 minutes, depending on type and mode. This amount of time could be unacceptable in some situations.

In poor-weather cases, operations below clouds with a small amount of standoff can continue, and radar sensors remain useful for some tasks. While free-fall weapons, such as laser- and GPS-guided bombs, are still viable at these standoff distances, their large lethal areas make employment closer than 900 ft from friendly forces a "danger close" situation. Moreover, the utility of laser-guided bombs can be limited if cloud ceilings are below 5,000 ft. Onboard guns are ineffective at these ranges. If low clouds are combined with GPS jamming, then most free-fall bombs would be less-effective or not available. In these circumstances, missiles and guided rockets still appear quite useful because of their responsiveness, lethality with small risk areas, and range. If guided rockets were procured with an anti-armor warhead and in larger quantities, and if they could be employed on additional platforms, they would be more useful in these situations. The drawback is that laser designation would be required, slowing down response time and increasing the possibility of user error.

Against High Levels of Air Defense

Against adversaries with moderately advanced air defenses, such as short-ranged SAMs, greater standoff distances (typically around 5–10 nm) will be needed unless these threats can be quickly destroyed, continually suppressed, or effectively countered. Operations against Iraq and Serbia, whose forces operated radar-guided guns and SAMs, resulted in several downed U.S. aircraft, despite robust mission packaging and SAM suppression efforts. Although onboard and offboard electronic attack systems are options, onboard systems can be costly and are typically thought of as a final layer of defense. Offboard systems, such as electronic attack and lethal SAM suppression aircraft, are not always available, nor are they always sufficiently effective. Without consistent suppression or very reliable on- and offboard countermeasures, operations from longer standoff ranges may be necessary.

Responsiveness is difficult from these ranges, although the powered weapons discussed in the previous section are still useful. The overall capacity of the force drops significantly as the standoff ranges lengthen too far to employ accurate, high-probability-of-kill weapons, such as laser-guided bombs, and Joint Direct Attack Munitions are pushed to the limits of their effective range. Furthermore, powered weapons with more standoff range are carried in smaller quantities than these 500-lb weapons, further decreasing capacity. The GPS-guided SDB I (GBU-39) and the multimode SDB II (GBU-53) begin to be highly useful in these circumstances. Area munitions for interdiction targets have insufficient range to avoid high levels of air defenses.

CSAR missions would be particularly difficult when defenses are more robust than the occasional small AAA or older MANPADS. Rescuers are likely to require a large support package, or IPs may need to wait until defenses can be suppressed. Tankers and rescue helicopters may drive the need for survivability, but their very low operating altitudes can emphasize the risk to escort aircraft operating in the Sandy role. The A-10C can survive against small numbers of certain types of threats, which is highly useful in CSAR missions, but improvements in threat air defenses could limit its ability to perform the Sandy role.

Against Very High Levels of Air Defense

The most stressing case would involve conflicts with near-peer nations, in which USAF aircraft on CAS and other missions could face advanced SAMs and fighter threats that can reach dozens of miles or more. New concepts for conducting counter-land missions or providing organic indirect fires may be required to operate against these threats if they cannot be countered rapidly and consistently. SAM suppression and fighter escort in support of the mission set will be required but still may not be effective enough or timely enough to allow the necessary ground force support. To counter threats under these conditions, a higher-speed long-range weapon is one option. However, this would also require a jam-resistant communication system to connect ground units with airpower operating from such long ranges, as well as forward-operating survivable sensors.

If standoff from medium-range SAMs is needed because these threats cannot be suppressed or countered, sensor capabilities and munition choices narrow significantly and gaps become quite noticeable. Sensor fields of view are small due to the high magnification necessary, limiting situational awareness, and many current platforms have difficulty generating small TLEs at longer ranges. This can be quite dangerous when coupled with long weapon time of flight as ground forces maneuver, and attacks are unlikely to proceed because probability of kill would be low and the fratricide risk high.

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Searching kill box areas with targeting pods at high magnification without an initial cue can easily take more than an hour and thus may not be operationally useful. Links to offboard sensors can be quite useful in limiting search areas. EO/IR sensors with large fields of view *and* high resolution are physically large, limiting their use on tactical aircraft. Larger sensors, such as the Multi-Spectral Target Sensor (MTS)–B on the MQ-9, provide much of the needed capability and so could operate as a team with a manned aircraft at safer standoff ranges, with remotely piloted aircraft (RPAs) operating closer or lower as needed. Video receiver capability would be required, as would secure beyond-line-of-sight communications between the RPA operators and the manned aircraft. Modern SAR sensors could still be employed from these ranges, and CAS tactics incorporating this sensor could be further developed, perhaps utilizing F-15E operations in Afghanistan as a starting point. At longer standoff ranges, marking targets would not be possible because laser pointers and rockets would be out of range completely.

At these standoff ranges, the SDB I and SDB II are the only relevant munition options. However, both are glide weapons, so their responsiveness is poor, taking more than a minute to arrive at the target. The SDB I cannot be used within 500 feet of friendly forces without significant risk, and it is not usable against moving targets. Having a relatively small warhead, the SDB I requires accurate coordinates to be effective, making it dependent on accurate targeting and potentially vulnerable to GPS jamming, particularly for extended times of flight.

The developmental SDB II munition provides the most options in this case, since it has long standoff, appears likely to be effective against most target types, and can be used fairly close to friendly forces.[8] It is specifically designed for use against moving targets; a Link 16 datalink permits target updates in flight, if not jammed, and a laser-guidance mode allows it to be guided to specific targets if a JTAC is available to provide laser designation. It also has autonomous seeker capability, but its ability to distinguish friend from foe is limited, and, as mentioned, it could take multiple minutes to arrive on target from these ranges.

To amplify the difficulty, adversaries with these advanced types of air defenses are also likely to possess the capability to jam GPS, voice communication systems, datalinks, and commercial satellite communication networks. Many of these links are vulnerable today, and given the dependence on communication in many of these missions, this threat could have a significant impact on effectiveness.

As these improved air defense cases arise in the future, it will be critical for the USAF to consider new munition types. The Air Force should also discuss with the Army what types of air support are possible in these environments, and how to maximize their utility despite the limitations. Gaps this dramatic emphasize the importance of maintaining the ability to locate and suppress or destroy longer-range air defenses in a tactical environment, with either airpower or indirect fires, as well as the need for countermeasures to allow at least short-duration operations in their engagement envelopes.

HOW DOES CURRENT EFFECTIVENESS CHANGE WITHOUT THE A-10C?

If the A-10C is retired, the FAC(A) and CSAR missions would be the most immediately affected, especially if qualified A-10C pilots were lost as well. Both of these missions have been quite rare in recent operations, so it is difficult to estimate effects on overall capability. For the FAC(A) mission, RPAs, such as the MQ-9, could provide some needed capabilities, but communication between ground forces and remote operators would be complex, subject to latency, and difficult to secure against advanced jamming threats. Currently, RPAs lack battlefield situational awareness due to limited sensor fields of view, and so they encounter limitations in highly dynamic situations requiring the highest level of situational awareness. Major improvements to RPA sensors and control stations would be needed to improve capabilities. The effect would be more dramatic for CSAR missions because, doctrinally, the A-10C currently plays an integral role as rescue mission commander, coordinator, and escort. It is likely that F-16, F-15E, and F-35A aircraft could take on many of these missions, but extensive training and, possibly, aircraft modifications would be needed. The A-10C is the only tactical aircraft equipped with the Lightweight Airborne Recovery System to allow secure communication with Hook or Combat Survivor/Evader Locator (CSEL) radios, so integrating the need for a (possibly beyond-line-of-sight) relay will increase complexity and the risk of failure in these missions.[9] F-35A aircraft, with advanced sensors, multiple radios, and increased survivability, are also a possible option for a future Sandy aircraft, but their use would require a significant effort to develop tactics and configure the aircraft for this purpose.

Additionally, the A-10C possesses unique capabilities for CAS missions. Any conversation with a JTAC or a web search for gun camera footage provides a visceral sense of the A-10C's core capability: providing very responsive, close fires in the middle of chaos. These are the circumstances in which the A-10C has a unique capability to shape the battle on the ground and provide effective ground support, sometimes simply by its presence, which is enabled by its high survivability at low altitudes against lower-end defenses. As demonstrated regularly since Operation Desert Storm, this capability is also a function of experience and training, which can total two to three times as many CAS training sorties as other aircraft, an ability to operate at slow speeds for both good situational awareness and target identification, a small turning radius (also a function of slow speeds), and a deep magazine that includes a gun that provides responsiveness, effectiveness, and low risk of collateral damage against almost all target types. Although training levels are a matter of policy that could be changed, and new weapons can deliver some of these capabilities on other platforms, there should be little argument that the A-10C is the most capable platform in these highly dynamic environments and its loss would reduce the USAF's ability to provide support in these cases.

However, the evolution of air defenses could prevent the A-10C from performing this mission with high survivability, whether it has been retired or not. The proliferation of advanced MANPADS and radar-guided SAMs, if they cannot be robustly suppressed or destroyed, could force the A-10C and other fourth-generation aircraft to operate at distances that would make them less effective in many ground support situations or lead them to suffer the high losses expected during the Cold War. The A-10C retirement debate should primarily revolve around how often highly dynamic and responsive air support will be needed in the future and where the proliferation of air defenses will limit the A-10C's contributions. The question for the Air Force is whether it is worth the cost—both in dollars and in lost opportunities—to maintain or pursue these capabilities.

WHAT CAPABILITIES WILL BE NEEDED TO PERFORM THE A-10'S MISSION SET IN THE FUTURE?

As we consider needs for the four missions specified in the NDAA language, it is important to keep in mind the larger context of how these missions fit into overall joint warfighting operations. Thus, the capabilities that will be needed for these missions must be considered in the context of ground forces—both in support of and for the purposes of attacks against ground forces. As the U.S. Army becomes more dispersed, lighter, and more deployable, it is making many trade-offs between vehicle protection and weight and between brigade operating area and the availability of division- and corps-level indirect fires (Pirnie et al., 2005). It will be important for USAF support capabilities to evolve along with the ground forces, so close consultation with the Army and Marine Corps should be a high priority.

Other elements of the joint force affect mission needs as well. On missions with terminal attack control from the ground, the capabilities, ground unit mission, and the JTAC's immediate situation greatly affect mission needs. A JTAC who can access video from an RPA and digitally transmit accurate coordinates to aircraft will require very different support from one with only line-of-sight voice contact or one who is on the move while under fire.

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Close Air Support Needs

Although there is no guidance on how responsive CAS fires will need to be in future conflicts, we note that other types of fires, such as counterbattery artillery, work to achieve timelines around two minutes, if possible (Pirnie et al., 2005). The simplest approach to ensuring responsiveness and providing presence to both friendly forces and adversaries is to operate close to the target area. Of course, this requires the right balance between survivability and standoff distance. Training can play a key role in responsiveness by reducing the time required for a JTAC to communicate its needs to the aircraft and correct targeting and fires. These missions almost always require the ability to locate and distinguish between friendly and enemy ground forces. When defenses allow, operations within visual range (typically on the order of one mile for target identification, or three miles for target detection) are useful for locating targets and maintaining awareness of broader areas. If defenses require several miles of standoff, a modern EO/IR targeting pod or onboard system allows detection, classification, and identification of targets beyond the reach of many tactical guns and SAMs—but generally at the expense of broad area search capability. In bad weather, aircraft must be capable of survivably operating below the cloud layer, utilizing coordinates from a JTAC on the ground or an onboard SAR sensor.

CAS platforms must be able to maintain contact with JTACs and FAC(A) to perform their mission. This has traditionally meant secure voice UHF and VHF radios. However, datalinks are taking on more and more of the communications burden. As JTACs and other Army units modernize with digital communication systems, such as Blue Force Tracker, it will be critical for CAS assets to take advantage of these new capabilities. Imagery and video sharing between controllers and aircraft is increasing as well, and future platforms should have the ability to create this shared situational awareness. Against higher-capability adversaries, security and jamming resistance will be required across all communication paths.

The effects that are needed from CAS missions can vary widely, from a show-of-force to destruction of multiple armored vehicles. Such a variety of targets creates a need to carry a diverse set of weapons with multiple fuzing options. Guns and powered weapons, such as the GAU-8/A, GAU-22/A, Maverick, Hellfire, and laser-guided rockets, that combine responsiveness and range with a small fratricide risk distance are very flexible and can provide some standoff. The need for a wide *variety* of munitions implies carriage of a large *number* of weapons, regardless of the number of targets. In highly intense cases, we found that a loadout sufficient to kill two armored targets per sortie was a minimum capability, with a preferred capacity closer to five kills per sortie. Platforms with more endurance can reduce the demand for tankers and the frequency of refueling. Swapping on-station aircraft during refueling is a potential source of delay and confusion. Similarly, we found that the ability to operate at poorer-quality airfields can multiply the number of available bases three- to 25-fold, which can allow closer operations and, hence, higher sortie rates.

Strike Coordination and FAC(A) Needs

As a supporting capability to AI and CAS operations, sensors will be critical on these missions because the aircraft is often responsible for finding and marking targets for strike aircraft. A slow-speed platform with good cockpit visibility has proven effective in the FAC(A) role since World War II. The challenge begins as air defenses force these vulnerable aircraft to operate at higher altitudes and longer standoff ranges. Modern sensors are capable of providing the resolution necessary for target classification at longer standoff ranges, but searching larger areas to detect targets is slower with targeting pods. Multiple radios are required since the FAC(A), and to lesser extent a SCAR Coordinator and Kill Box Coordinator, often coordinate with several aircraft simultaneously, acting as a relay between ground forces, strike aircraft, and command-and-control nodes.

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> In general, these are complex, highly dynamic, and often high-risk missions that can require very precise employment of weapons in difficult and dangerous circumstances.

Air Interdiction and Armed Reconnaissance Needs

A key component of these missions involves locating targets with large or nonexistent cues.[10] So minimizing search times is a key consideration, requiring sensors with large fields of view. SAR and ground moving target indication (GMTI) sensors are particularly useful in these missions because vehicles and structures are more likely targets than personnel, and they offer more standoff range than EO/IR sensors. A targeting pod can take 10–60 minutes to search a 25-nm by 25-nm area, while a SAR or GMTI radar could do it in less than 10 minutes at a significantly longer standoff range, but with poorer capability for target identification. The ability to connect with platforms such as RPAs or Joint Surveillance Target Attack Radar System (JSTARS) can allow the use of offboard sensors that may be able to see deeper into the battlespace. But this link likely requires beyond-line-of-sight communications—via satellite, for example—which are susceptible to jamming. These missions, especially AI, can be drivers of large payloads. Since groups of targets are more likely, and the missions tend to be farther from basing, large-payload aircraft are significantly more efficient. Area munitions that are compliant with DoD policy and are capable of striking moving targets, such as the CBU-105, are particularly useful. Our most stressing interdiction cases, involving large invasion forces, could require kills of 500 vehicles per day for success. As a conservative example, with a sortie rate of 1.5 per day, if, pessimistically, one-third of interdiction sorties find and attack targets and each attack only kills two vehicles, an unrealistically large force of more than 500 aircraft could be needed. Sufficient capacity for these missions requires a combination of sensor quality, payload size, sortie rate through basing location, and force size.

CSAR Needs

These missions are likely to continue to demand high levels of responsiveness, both in an operational sense to respond quickly from alert locations and at a tactical level to respond to pop-up threats. High speed is useful in both situations. However, there are also demands for slow speed loiter and high turn rates while remaining near an IP, searching for threats, and escorting much slower helicopters. High-quality cues to an IP's location are often not available; thus, the Sandy aircraft can be faced with the very difficult sensor problem of finding a single individual, possibly in rough terrain and foliage, regardless of time of day or weather. Turreted sensors and dual-seat aircraft would be highly useful in the workload-intensive CSAR environment. Unique radios are needed in the CSAR mission, primarily to communicate with an IP in low-probability-of-detection modes. Multiple, secure, and jam-resistant radios are a must, since the Sandy aircraft will often be coordinating with several aircraft simultaneously, acting as relays between aircraft, refueling tankers, and reaching back to command-and-control nodes.

Table 2 (on the next page) summarizes mission needs, looking across missions for capabilities that would contribute to high effectiveness in multiple areas. The table is organized by key characteristics: survivability, responsiveness, target acquisition, communications, weapon effectiveness, and capacity. Other organization schemes are possible, but our analysis found these six attributes were the most critical for overall mission effectiveness.

As a final note, it is difficult to overstate the importance of training across all of these missions. In general, these are complex, highly dynamic, and often high-risk missions that can require very precise employment of weapons in difficult and dangerous circumstances. It is very likely that a well-trained pilot can be effective in almost any platform, while a poorly trained one will have difficulty even in the best aircraft. Regardless of the mix of platforms the Air Force utilizes for this mission set going forward, it will be critical to take advantage of current experience and expertise and to ensure that knowledge in these areas is spread to the most appropriate communities.

Table 2. Key Mission Needs and Capabilities

Characteristic	Need	Capabilities	Most Relevant Missions
Survivability	Employ sensors and weapons at acceptable risk level	• Radar and missile warning needed to respond to unexpected threats • Robust airframe • Effective countermeasures • Reduced detectability • Offboard support	All
Responsiveness	Operate as close as possible to target area	• High survivability	All
	Rapidly put weapons on target	• Guns and missiles much faster to target than free-fall bombs	CAS and CSAR
	Promptly engage pop-up threats; react to new target areas and changes in ground situation	• High platform speed • High turn rates	All
Target acquisition	Visual very useful for area search	• Binoculars aid target identification • Distributed Aperture System–like systems could greatly expand short-range "visual" utility • High survivability	CAS, FAC(A), and SCAR
	Magnified EO/IR for search and identification at longer standoff ranges	• EO/IR targeting system	All
	Broad area search and identification capabilities at longer standoff ranges	• SAR and GMTI radar modes • Operating at multiple frequencies could improve camouflage detection	AI and SCAR
	Ability to utilize offboard sensor information, such as RPAs that can push sensors forward	• Link 16 • Remotely Operated Video Enhanced Receiver (ROVER)	All
Communications	Voice communications with ground forces	• UHF and VHF with HAVE QUICK II frequency-hopping protocol and communications security	CAS and FAC(A)
	Digital communications with ground forces	• Compatibility with variable message format (VMF), situational awareness datalink, Link 16, and ROVER links; must ensure future compatibility as Army evolves	CAS and FAC(A)
	Multiple radios for strike coordination	• Three radios appear reasonable compromise	FAC(A), SCAR, and CSAR
	Beyond-line-of-sight links with jam and intercept resistance needed on deeper missions	• New capabilities may be needed	AI, SCAR, and CSAR
	Securely communicate with isolated personnel	• Digital links to CSEL and Hook radios	CSAR

Table 2—Continued

Characteristic	Need	Capabilities	Most Relevant Missions
Weapon effectiveness	High probability of kill to reduce payload needed, sortie demands, and risk	• Warhead and fuzing diversity	All
	Effectiveness against soft and armored targets	• Multimode warheads	CAS, AI, and SCAR
	Effectiveness against stationary and moving targets	• Very fast or appropriately guided/ controlled munitions	CAS, AI, and SCAR
	Small fratricide and collateral damage risk distances	• Limited blast and fragmentation effects	All
	Carriage of large diversity of weapons	• Compact weapons that enable large payloads • Multiple seeker and warhead options that provide flexibility and robustness • Cockpit-selectable fuzing	All
	Responsive fires from over 15 nm of standoff or more	• New forward-firing, higher-speed weapon	CAS and AI
	Ability to mark targets day or night	• Laser pointer, guided low-lethality marking expendable	FAC(A) and CSAR
Capacity	Kill two to five targets per sortie	• Sufficient loadout of high-lethality weapons	CAS and AI
	Minimize handoffs from aircraft to aircraft	• Long endurance useful, but must be matched with loadout	CAS, FAC(A), and SCAR
	Increased basing options for fewer political restrictions, more responsiveness, longer loiter, and less tanker demand	• Loaded takeoff and landing distances around 5,000 ft • Runway load classification number capability <35	All

Notes

[1] We examined sensor and weapon effectiveness for the F-35A, but not survivability, due to the classification level of this analysis.

[2] Armed reconnaissance is also known as airborne alert AI (XAI).

[3] There are some mission definition inconsistencies between the NDAA language and USAF doctrine. According to AF publications, SCAR is not an A-10 mission, but the platform is capable of executing the SCAR derivative mission type and is frequently tasked to complement and support counterland operations involving CAS and AI. Also noteworthy, troops-in-contact is not a mission, it "is an advisory call to increase awareness and highlight the urgency of the ground situation" (Joint Publication 3-09.3, 2014).

[4] The Air Force doctrinally characterizes a low-risk air defense environment as "permissive combat airspace," not "uncontested."

[5] We did not examine a case with no air defenses because all of the missions would presumably be performed against armed adversaries.

[6] We did not conduct this analysis for the F-35A because the signature information needed is available only at higher classification levels.

[7] Assuming a sortie rate of 1.5 per day.

[8] We were unable to obtain detailed information on the SDB II warhead, so these assumptions are based on the general characteristics of the warhead, such as its type and weight relative to other warheads whose effectiveness is known.

[9] Other similarly equipped aircraft include the AC-130H, HC-130P/N, MC-130P, and RQ-4.

[10] Although interdiction missions can also occur against fixed, pre-located targets, this is less a part of the A-10C's mission set.

Acknowledgments

This project would not have been possible without the contributions of many people we met with over the course of our research. They provided information on specific programs and capabilities, as well as thoughtful discussion of the issues associated with close air support and the other missions under study here.

At Air Force Headquarters A5R-C, Lt Col Eric Janski served as our action officer, providing guidance and support throughout the course of the project. He provided operator perspectives on the missions and platforms under study here and assisted with the critical task of tracking down needed data and contacts in a timely fashion. He also organized fact-checking efforts with platform subject-matter experts, which eliminated several issues. We appreciate his patience and good humor throughout this study.

Many Air Force and other Department of Defense offices assisted us with data for this effort, including Tara Wichers and Terry Atkinson at AFMC/EBMS, who provided us with information on the SDB II; Dan Patt and Marshall Frith at DARPA, who provided many details on their Persistent Close Air Support program; and Gary Butcher and several others at AFRL/RYWW, who were of great assistance in obtaining an update to the Modeling System for Advanced Investigation of Countermeasures (MOSAIC) SAM model. At Air Combat Command, Brian Kieffer and others regularly answered questions about weapon programs; we thank them for their patience and willingness to answer our inquiries. CMSgt Craig Janke and Maj David Anderson provided much-needed insight into modernization of JTAC equipment and manning. At Pacific Air Forces, MSgt David Bickel was very kind to share his insights into JTAC operations and, likewise, Lt Col Christopher Forrest on his experiences flying the A-10C.

Amy Howell, Gary Liberson, and their staff at Lockheed Martin were instrumental in obtaining performance and other information about the F-35A program. We appreciate their assistance.

At RAND, the technical reviewers, Bart Bennett, James Chow, and John Matsumura, provided thoughtful, detailed critiques of earlier drafts of this document and the issues at the heart of this effort. The report is much improved because of their efforts. RAND colleague Randy Steeb also provided helpful insights into Army perspectives on close air support, and we appreciate the comments of RAND Army Fellows LTC Matt Olson and MAJ Brent Williams on portions of the draft document.

Any errors or omissions remain the sole responsibility of the authors.

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About This Report

Recent U.S. Air Force planning documents, such as the Global Precision Attack Core Function Support Plan for Fiscal Year (FY) 2017, have included a drawdown of the A-10C force from 283 aircraft to zero by 2019 (now scheduled for 2022). In 2007, the fleet began upgrades to the A-10C variant with a Precision Engagement modernization upgrade and a service life extension for 173 aircraft with the A-10C Wing Replacement Program. However, fiscal and manpower pressures—combined with the upcoming entry of the F-35A into service—have led the Air Force to conclude that A-10C retirement is the lowest-risk option to meet its budgetary goals.

However, Congress rejected Air Force divestiture plans in FYs 2014, 2015, and 2016 with legislation that did not allow funds to be used to "retire, prepare to retire, or place in storage or on backup aircraft inventory status any A-10 aircraft." The FY 2016 National Defense Authorization Act, passed in November 2015, also contained language in Section 142 directing the Secretary of the Air Force to "commission an appropriate entity outside the Department of Defense to conduct an assessment of the required capabilities or mission platform to replace the A-10 aircraft." In May 2016, RAND Project AIR FORCE was commissioned to perform this independent assessment. This report documents the results.

The research reported here was sponsored by Maj Gen Timothy Fay, Director of Strategic Plans, Office of the Deputy Chief of Staff for Strategic Plans and Requirements, Headquarters U.S. Air Force, and conducted within the Force Modernization and Employment Program of RAND Project AIR FORCE as part of an FY 2016 add-on study titled "Congressionally Directed Assessment of Required Capabilities to Replace the A-10C."

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RR-1724/1-AF