Airpower Trends 2010

The Future Is Closer Than You Think

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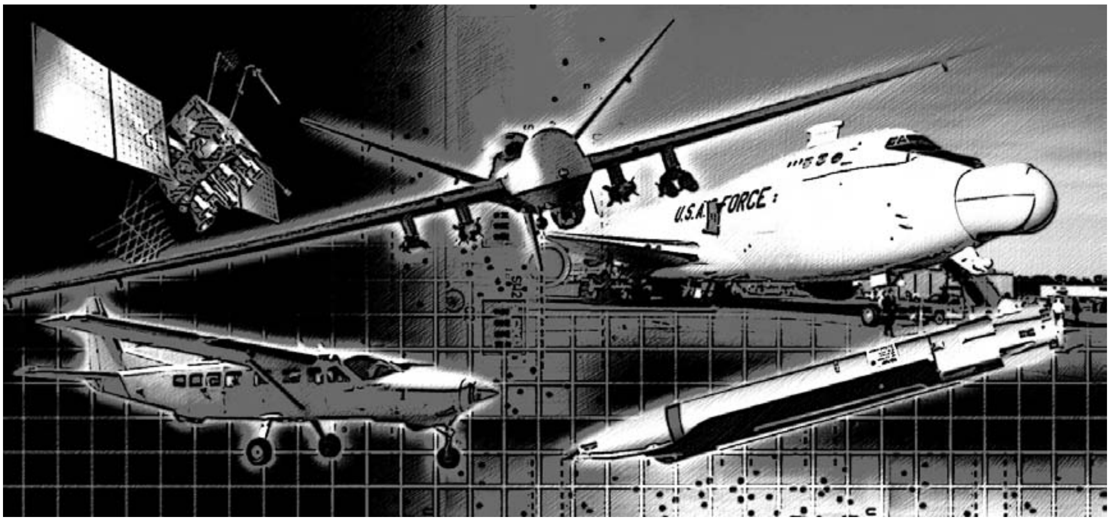
The author examines the state of airpower in the near future by addressing three broad areas in which radical change has already occurred. First, he shows that close air support has undergone a revolution in efficacy by improving networked coordination, using simpler delivery systems, and developing one-shot-per-target capabilities. Second, he examines advances in unmanned aircraft systems and discusses the impact of these platforms. Third, the author notes that airborne laser systems and other directed energy weapons stand poised to deliver near-instantaneous effects from unparalleled standoff distances. Ultimately, he argues that these systems are alternatives to, not additions to or adjuncts of, the manned force.



Technologies in place today have produced unmanned systems capable of replacing manned aircraft. Will we react to the challenge or act on the opportunity?

THE AIR FORCE has always seen itself as the force of the future. We live in a future that our predecessors built—with jet aircraft, missiles, operations from space, precision munitions, and, now, cyberwarfare. However, our record of innovation in using those technologies is less impressive. Jet fighters fought like fast biplanes of World War I vintage until Col John Boyd developed the fundamentals of energy maneuverability in the 1960s. Even then, it took another decade for Colonel Boyd's supporters—his fighter mafia—to implement the concepts throughout the Air Force.[1] Practical precision munitions, introduced during the Vietnam War, initially offered nothing more than a way to destroy fixed targets without the 1,000-plane raids of World War II. Col John Warden's revival of the strategic-web targeting theory in his book *The Air Campaign: Planning for Combat* (1988) explicitly set out the revolutionary nature of this capability. The debate continues today with the (ongoing) development of the theory of effects-based operations.

Tactics in the field lead institutional innovation. This traditional path makes for good doctrine but is slow—glacial in peacetime—and seldom anticipates change. There is much truth to the saying that doctrine is about fighting the last war. Faced with the challenge of a new conflict, our young airmen (as well as soldiers, sailors, and marines) are adept at solving problems with the tools and technologies at hand. Eventually, these innovations may find their way into service doctrine. The pace of doctrinal change seems locked to generational changes in Air Force leadership. Must we wait for today's captains and majors fighting in Iraq/Afghanistan to be promoted before we come to grips with the future?

Technologies now reaching the flight line or already in combat can radically alter the way we fight. This article briefly explores three broad areas that not only represent better ways of doing business but also may transform the business itself. Not the stuff of science-fiction scenarios or nanotech warfare, these capabilities are on the ramp today.

Precision Munitions and the End of Close Air Support As We Know It

A transformation in close air support (CAS) is occurring through the combination of a common precision frame of reference for the entire joint force provided by the global positioning system (GPS), broadband communication linkages (tactical Internet), and cheap processing power that controls maneuverable weapons. The proximity of forces in contact puts a premium on situational awareness and accuracy, thus making CAS a demanding mission. The "close proximity to friendly forces" and "detailed integration of each air mission with the fire and movement of those forces" define CAS in Air Force doctrine.[2] Consequently, in the past, CAS aircraft had to fly over the battlefield to clearly identify enemy and friendly positions. Once oriented, the pilot then had to maneuver close to the target to deliver weapons. Close proximity offered the only way of attaining sufficient accuracy to destroy the enemy without collateral damage to friendly forces. Overflying the battle required that the CAS platform be maneuverable and tough. Technology in the field today, however, radically changes this equation.

The availability of real-time intelligence, observation, and targeting referenced to GPS coordinates has eliminated the need for CAS aircraft to overfly the battlespace for situational awareness. The lengthy coordination among joint headquarters, ground observers, and pilots can now take place in seconds over tactical networks. The ground-force commander can provide the current disposition of his or her forces, specify exactly where fires are needed, and deliver that information anywhere on the battlefield.

Precise locations of friendly and enemy forces delivered directly to an aircraft supply the necessary battlefield orientation, permitting near-immediate weapons release. Guidance on board the weapon then maneuvers it to impact. The aircraft no longer has to close with the target to ensure accurate delivery. In turn, the fact that CAS aircraft can now stand off from the battlefield reduces the need for maneuverability.

Furthermore, avoiding the immediate battlespace keeps these aircraft out of the threat envelopes of small arms, antiaircraft artillery, and small surface-to-air missiles, further relaxing the performance requirements for CAS systems. Lower performance means that simpler, cheaper systems can carry out the mission.

Precision targeting also reduces the weapons yield necessary to destroy a target. In principle, precision allows delivery of every munition within feet of the point designated by a tactical commander. Concentrating the weapon's effect on the target reduces the yield needed for target destruction as well as the number of weapons per objective; it also allows for delivery of fewer, lighter weapons by smaller systems, which can be much less complex since the detection and aiming tasks have effectively moved from the delivery platform to the network and the munition, respectively. Moreover, the supported ground force's surveillance systems or other parts of the intelligence, surveillance, and reconnaissance "cloud" over the battlefield can put immediate poststrike observation of a weapon's effects on the network.

Because precision weapons' one-shot, one-kill capability reduces the number of weapons required per target, we can place more weapons on existing platforms or use smaller platforms as effectively as today's CAS aircraft. We can already see both ends of this spectrum in use. At the high end, B-52 and B-1 "bomb trucks" are releasing single precision weapons from their capacious bomb bays to strike individual targets on call. At the light end, Reapers (and, very soon, Cessna Caravans) are delivering Hellfire missiles.[3] This ability to kill more targets with the same number of weapons reduces the number of aircraft required to perform CAS.

Opposing this trend toward fewer CAS platforms is an increase in the utility of—hence, the demand for—CAS.[4] Smaller weapons yield drastically shrinks the scope of collateral damage and allows weapons delivery closer to friendly forces, expanding the usefulness of CAS to those forces and lowering barriers to its use. Significantly, not all of this demand need be satisfied from above, though airborne CAS will likely remain the most responsive option. Guided munitions for artillery and mortars can provide similar precision from small, unit-portable weapons.

The combination of networked coordination, simpler delivery systems, and one shot per target makes lower-echelon control of CAS feasible, pulling it out of the central air and space operations center (AOC) and moving it down to the ground force's tactical operations center. We see this today in the air tasking orders in Iraq and Afghanistan. During the author's tenure commanding the Joint Special Operations Air Component in 2005, the majority of CAS sorties launched without a target as "XCAS," tasked in the air to meet immediate needs of the ground force. The AOC had largely become a logistical node, providing and sustaining armed aircraft on call for ongoing operations. The detailed coordination called for in CAS doctrine shifted from the joint headquarters level to the ground tactical operations center, where network-linked overhead sensors supplied the battlefield overview directly to the CAS platform, air liaison officer, and troop commander. This trend is also evident in the development of the joint air-ground control cell concept discussed in Air Force Doctrine Document 2-1.3, *Counterland Operations*.[5]

In combination, these factors also diminish the logistical-support footprint for CAS, allowing both control and basing of delivery systems to move forward to lower echelons of the tactical force. A moveable complex of light unmanned and manned aircraft supported by a distributed intelligence, targeting, and control network can replace a squadron of A-10s at a fixed airfield—witness the Army's Task Force ODIN (observe, detect, identify, neutralize) in Iraq. Combined within an Army combat aviation brigade are manned and unmanned sensor aircraft as well as manned and unmanned light aircraft and helicopters. Traditional linkages to artillery support, itself capable of delivering precision munitions, also remain. A networked surveillance and targeting system supports the tactical force commander, who now controls a package of systems offering an overview of the battlefield, target detection, and immediate firepower. Though initially designed to prevent the emplacement of improvised explosive devices on Iraqi roads, Task Force ODIN has all the capabilities needed to support troops in contact with the enemy—in short, to do CAS.[6] Of course, today's fight in Iraq and Afghanistan is as unique as any other conflict; however, the above logic holds up well across the range of military operations.

Large-scale, mechanized (conventional) conflict does not change the CAS equation for the tactical commander. If anything, it expands the need for speed and precise effects. Primary changes include an increase in the intensity of the ground threat to CAS aircraft, potential airspace congestion over the battle, and growth in the size and complexity of the fight.

Unmanned systems in use today would prove effective in a conventional fight. Standoff delivery of precision weapons from outside the range of enemy defenses makes more intense air defenses irrelevant since the delivery platform would rarely come within reach of those defenses.[7] In addition, smaller delivery platforms present a smaller detection signature. The visual, infrared, and radar signature of a low-powered, composite Predator-type platform is significantly less than that of traditional CAS aircraft—stealth on the cheap. Large numbers of low-cost platforms can also saturate defenses or make losses tolerable.

Similarly, in situations requiring airpower, the greater effectiveness of each precision weapon negates the increase in enemy forces in a conventional fight. Each CAS platform can destroy large numbers of targets using individual munitions or precision area weapons such as the CBU-105 (sensor-fused weapons in a wind-corrected munitions dispenser).[8] Rather than building a wall of fire across the battle front, massed CAS changes to become the massed effect of numerous small explosions directly on each battlefield target.

We must still contend with the perennial problem of operating multiple types of systems in constricted airspace over the battle. We are addressing the problem (painfully) today in the skies over Iraq as AC-130 gunships, helicopters, fighters, Predators, and other sensor platforms regularly operate in support of a single operation—so far without an actual collision. Deconfliction in a less permissive environment would pose even more of a problem—but only if we need to operate multiple platforms directly above the fight. Covering a given number of targets with fewer platforms standing off from the fight would diminish the need to operate in congested airspace over a conventional battlefield.

Large-scale, mechanized combat not only increases the physical size and scope of the battle across multiple tactical engagements but also calls for more coordination across the theater. Existing information networks already distribute tactical information around the globe. Adding capacity to these linkages presents a logistical problem of securing sufficient bandwidth—not just a technical one. Moving the information where it is needed allows us to focus command and control at any given level—from tactical to theater strategic. We can synchronize multiple tactical engagements centrally, with execution decentralized to appropriate network nodes. Of course, this need for bandwidth to move information and commands remains a major vulnerability for all operations in a large-scale conflict.

Ultimately, these trends will push toward a smaller/simpler Air Force CAS force, a smaller "combat" role for the AOC in the CAS fight, and more control of the CAS mission by tactical commanders. By 2010 a typical call for CAS might resemble this scenario:

> A company-level commander in the fight locates targets from an intelligence picture that synthesizes everything from ground-platoon reporting, overhead visual images, infrared sensors, radar, and radio-intercept information uploaded to a tactical network. The commander "points and clicks" to designate specific targets and to upload precision coordinates to the tactical net. Personnel designate mobile targets by type to specify seeker settings for appropriate weapons. They also determine no-fire areas from reported GPS locations of friendly units, and go online to calculate frag patterns for collateral damage.
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> Once placed on the net, the information is available to all weapons within range of the fight—anything from mortars and artillery to unmanned and manned aircraft. Orbiting outside the battle area, these might include a few large aircraft, each with many weapons, or a large number of manned/unmanned light aircraft, each with fewer weapons. Weapons-delivery systems "bid" for targets based on their capabilities, each system making specific targeting assignments, and then fire weapons that converge on the battlespace. Detailed flight-path coordination is unnecessary since only the weapons, not the delivery systems, enter the area. Intelligence, surveillance, and reconnaissance systems from the supported ground force and theater-level assets put strike results on the net.

> The AOC carries out its role of launching manned and unmanned CAS aircraft, directing them to holding orbits. It also monitors the status of fuel and weapons, keeping the orbits resupplied by managing tanker support and launching replacement CAS aircraft. The AOC has little to do with the tactical fight.

Unlike many forecasts, this is not speculation about new technology but observation and synthesis of trends in current equipment and tactics used today, taken to their logical conclusion. Still missing is a comprehensive machine-to-machine interface to share existing information and allocate weapons to targets.

Our challenge lies in accommodating this reality. What force structure does the CAS mission require? How many A-10s, F-16s, and F-35s can MQ-9s replace? Do we lead this charge or cede the mission area and funding to ground forces?[9] The revolutionary impact of the GPS, communications, and computer power on CAS comprises one aspect of a broader application to airpower.

Unmanned Aircraft Systems: Pilot Chips instead of Wings

The evolution of unmanned aircraft has been constrained by the need to respond to the complex aerodynamic and navigational requirements of controlled flight. Moreover, the tactical aspects of combat missions demand immediate human decisions and control. Nevertheless, capabilities developed and deployed in the last two decades now allow UASs to conduct some combat missions effectively.

UASs are as old as flight itself. The first flying machines were unmanned models and gliders built to investigate the fundamental principles of flight. Development then turned to putting a man into the machine. Shortly after the Wright brothers' first successful powered flights, however, certain military missions required removal of the man from the aircraft.

The Kettering unmanned aerial torpedo of 1917—the Bug—was the first practical military UAS.[10] A preset system of electrical and pneumatic controls flew this aircraft and released its payload—hopefully, on the target. Although World War I ended before the Bug saw action, this unmanned system set the tone for future UAS development. The challenges of making a successful powered takeoff and landing limited UASs to single-use systems launched by catapult, air, or track—that is, flying bombs. In situations that precluded the launching of the UAS—for example, World War II's Aphrodite systems, which employed modified heavy bombers stuffed with explosives—a pilot flew the takeoff and then parachuted from the explosives-laden aircraft, at which point a following aircraft took over by radio control.[11]

Some previous unmanned aircraft could be recovered and used again if equipped with a parachute-recovery system, but their complexity and the inevitable damage that occurred during the process prevented a quick turnaround for aircraft-like operations.[12] We developed recoverable systems when we needed to limit costs (target drones) or retrieve recorded information (reconnaissance drones).

In the 1970s, a better understanding of aerodynamics and the availability of computers to execute control algorithms solved the problems of taking off and landing safely. Not developed for unmanned systems, the capability grew from the continued refinement of autopilot systems for commercial aircraft. Driven by safety requirements and a need to operate more reliably in poor weather, avionics companies developed systems that could use an aircraft's autopilot to fly a coupled precision approach. A logical extension of this capability was the addition of radar-altimeter information to bring the aircraft all the way to the landing flare. Economics drove acceptance of the technology, allowing airlines to provide more reliable service in poor weather.[13]

A corresponding economic need, this time to save fuel costs, led to the concurrent development of autopilots that could control engine power settings as well as aircraft attitude and flight altitude. The autothrottle optimized the engines' power setting and aircraft climb rate to save fuel. It was only a short step to add logic that could extend this control from aircraft brake release to touchdown.

Accurate navigation remained a problem. Autopilots could guide an aircraft along an airway or approach path but could neither "see and avoid" obstacles nor determine a precise position without external navigation aids. Either inertial navigation systems or complex automatic star trackers could provide aircraft position but not with the precision needed for flexible operations outside a well-defined route structure.

The development and deployment of terrain-following radar systems coupled to an aircraft's autopilot (F-111) added obstacle-avoidance capabilities. The problem of avoiding other air traffic is yielding to cooperative aircraft-transponder networks, with aircraft sharing precise information about position and velocity.[14] Finally, the level of accuracy provided by the GPS enables aircraft to determine their position to any practical level of precision.

Together, these developments have given us aircraft like the Global Hawk, able to operate autonomously from initial takeoff to subsequent landing at another airfield anywhere in the world. Now that pilots possess an airplane capable of flying itself, the toughest task remaining for them on a routine flight involves navigating the ground traffic between the parking ramp and the runway.

We have solutions in hand to get unmanned systems from takeoff to a destination—more than enough capability for straightforward missions like cargo delivery. No technical reason prevents us from deploying an unmanned tactical cargo air bridge by 2010. Equipping a constellation of QC-27 aircraft with the brains from Global Hawk would do it. Farfetched science fiction? Not at all: the 17 November 2008 issue of *Aviation Week and Space Technology* reported that the US Army has tested an "optionally piloted" Cessna Caravan for "utility transport in routine, but sometimes dangerous, battlefield and area-of-interest reconnaissance and patrol missions."[15]

We seem to have the practical capabilities for routine operations in hand—but not the doctrine and attitudes. However, it is instructive to note that commercial airline operations are adopting autotakeoff/pilot/land systems in the name of increasing flight safety. Resistance to unmanned operations usually centers on safety, specifically the problems of dealing with emergencies or nonroutine operations.

Actually, executing emergency procedures is one of the easier problems to solve. Generations of thought and experience have given us very good algorithms to deal with emergencies—specifically, the emergency-procedure checklists in every flight manual. For each potential problem, we have a step-by-step procedure to analyze problem indications, take action, observe the results of the action, and take further action if necessary. Autonomous implementation simply requires that the problem indications be available to the UAS's controlling computer and that the various controls, switches, and circuit breakers be activated by that computer.

We also have a model for dealing with unusual or intractable emergencies. Currently, a pilot declaring an in-flight emergency quickly receives support from a team of experienced aircrew, leadership, and engineering personnel. We can gather the same team for a UAS, but that team now determines additional actions to transmit to the remote aircraft.

The remaining problem—making nonroutine tactical decisions required in combat—represents our present justification both for the continued use of manned aircraft and the close manned supervision of UASs. Today's solution is to keep the human in the loop, even if the loop stretches through a satellite linkage to Nevada. This demands plenty of bandwidth to pass the information needed to maintain the remote operator's situational awareness. The communication linkage also imposes a time delay as the signal travels from the UAS to the operator and back. Global operations using a satellite relay incur one-way transmission delays of at least a quarter of a second.[16] A total round-trip delay of half a second may not sound like much, but the lag is more than enough to cause problems during rapid aerodynamic maneuvers. Routine delays may be much longer, depending on details of the transmission route and any required computer processing of information or commands.

To deal with nonroutine mission operations, a UAS must have some ability to detect a change to the preplanned mission and then develop and implement a solution. En route, the problem becomes how to maneuver the UAS around unforeseen obstructions, whether terrain, weather, threats, or other aircraft. Detecting them requires either an appropriate sensor—mapping radar, threat-warning receiver, or collision-avoidance system—or information provided by off-board sensors through a network. None of these is new technology; all are available today.

After detecting the obstruction, the UAS must replan its route to avoid the obstacle. Once again, we already have the solution in the field: automated software for route planning and in-flight replanning. Today's UASs, and some airliners, are not "flown" during the en route portion of their flight but are directed by changing the desired routing for the autopilot—using a mouse click instead of the control stick. For UASs, moving implementation of the software from the control cab to the aircraft themselves represents just a small step. Determining the need to revise a route involves only the incorporation of software to allow the UAS to update its internal map autonomously, replan its route as required by traffic or threats, and update any relevant airspace controllers.

Once in the target area, a UAS must detect and locate its objective, release weapons, and conduct any required offensive/defensive maneuverings. How close are we to pushing these decisions forward to the UAS?

Detecting and locating targets is already a heavily automated task. We deploy a network of sensors across the battlespace and analyze the resulting information with a series of computer tools. Today, we manually transfer this information to the flight crews, who then manually enter it into their aircrafts' systems. Transferring the information directly from a targeting cell in the AOC to the UAS only simplifies the process.

Striking fixed targets, whether preplanned or designated by a ground/airborne observer, is straightforward. The UAS simply transfers the provided coordinates to an onboard weapon and maneuvers to the weapon's release box.

Moving targets are more demanding because we must search the area to locate them. They impose more demands on the UAS's sensors, or they require more detailed external direction. However, we have already deployed or demonstrated solutions to this problem with existing missile seekers, like that of the imaging infrared Maverick, and with the laser Joint Direct Attack Munition.[17] The key is recognition of targets—and friendlies—an area in which we may require human intervention for some time yet.

In the target-rich environment of high-intensity combat, truly autonomous UAS operation is now feasible. Existing sensor-fused weapons and other precision munitions can both find and strike conventional targets. More ambiguous combat environments, such as counterinsurgencies and urban fights, will need to maintain a human in the decision loop to designate targets and approve weapons release. Assuming adequate bandwidth, this is how we do business today.

Although the problem of offensive and defensive maneuvering remains, we can make some general observations. The fight beyond visual range should remain within the capability of today's UAS since the problem is essentially limited to target detection and weapons release. For a close-in fight, the UAS is probably not yet ready. This mission would likely require much more complex control laws than we now use. Existing logic for maneuvering an air-to-air missile to an intercept would probably not prove sufficient to solve the more complex problem of maneuvering for a missile or gun shot while preventing the target, and other enemy aircraft, from attaining a firing solution on the UAS. Using a human in the loop would run up against the previously mentioned time-delay problem as well as require excessive bandwidth to provide the remote controller with situational awareness. Development of a practical air-to-air-fighter UAS will depend on future improvements in both framing the maneuvering problem and creating the artificial intelligence to solve it.

Defensive maneuvering against ground threats poses a less difficult problem. Due to high cockpit workloads and the need for short reaction times, existing countermeasures suites generally operate automatically, once armed. A UAS could arm/disarm its countermeasures, based on known threats, onboard threat detection, or mission profile.

One argument maintains that incorporating all these capabilities will drive up the size and cost of a UAS, negating any advantage over a manned system. The flaw in the argument is that, to put a UAS in combat, we don't need hardware as much as we do software and computing power. Making a bigger, smarter "brain" takes grams of silicon—not pounds of aluminum. Furthermore, the UAS does not require the volume, protection, and environmental systems needed to carry an aircrew.

Additionally, many of the technologies that enable UASs are not carried on the airframe. Precision GPS navigation and targeting information from the network harness a huge infrastructure with minimal equipment on board the UAS. Of course, relying on off-board support highlights the major UAS vulnerability today—bandwidth. Limited capacity and vulnerability to electronic attack make this the UAS's weakest link. Increasingly autonomous UAS operations should render this problem more tractable by reducing the amount of external information needed by the aircraft.

That said, if UASs are so capable, why are we not fielding them in greater numbers? Ultimately, it comes back to resources. The demands of maintaining and updating the inventory of manned aircraft already exceed available funds in the Air Force budget. With every dollar spoken for, the Air Force still needs more F-22s, new tankers, a new combat search and rescue platform, and more airlift, as well as repairs and upgrades for the existing fleet. There are simply no resources to increase the inventory with a large number of UASs—and we are unwilling to trade U-2s for Global Hawks or A-10s/F-16s for Reapers. Despite the UAS's demonstrated operational capability, we do not seem to have reached a tipping point in our attitudes.

As with the adoption of the Predator and its successor combat UASs, we are seeing field utility and the troops' creativity advance the mission—not service leadership or the acquisition community.[18] Another revolutionary capability is emerging from a similarly long and difficult saga of development and acquisition.

Directed Energy Weapons: Revenge of the Battle Plane

In late November 2008, the YAL-1 airborne laser (ABL) completed the first ground test of the entire weapon system integrated aboard the aircraft, generating and directing the beam onto a simulated target and thereby preparing the way for flight tests in 2009.[19] What are the implications of an operationally useful directed energy (DE) weapon? The designed mission of the megawatt-class laser on the ABL is to destroy missiles at ranges in excess of 200 miles.[20] However, like the creative operators who placed a 105 millimeter howitzer in a C-130, the developers of the ABL are already discussing the weapon's effectiveness against air-breathing targets.[21]

Speed-of-light/line-of-sight weapons like the laser on the ABL are fundamentally different from kinetic weapons. Line-of-sight precision ensures one-shot, one-kill effectiveness. Speed-of-light response ensures that the target has no warning to make evasive maneuvers or employ countermeasures.[22] If the technology proves practical and affordable, a DE weapon will provide a near-instant kill of targets detected within its effective range. Echoes of Giulio Douhet's combat plane able to clear its way through the skies with superior firepower can be heard as the ABL takes flight.

At its maximum range, the ABL weapon is designed to weaken a target's structure enough to cause aerodynamic and acceleration forces to break it up. Elementary physics assures that the laser beam's power becomes substantially more destructive as the range decreases. At shorter ranges, the beam will have less spread and less atmospheric absorption. We can expect a laser that can kill a relatively thin-skinned target at 200 miles to have much more capability at 50 miles—solidly in the medium-air-to-air-missile range.

At first glance, the ABL would seem the ultimate fighter on offense or defense, able to kill any detected aircraft or missile coming within range. Countering the ABL would place a premium on stealth (preventing detection and targeting), avoidance (remaining outside the laser's effective range), numbers (saturating the engagement area), or weather (operating below weather the laser cannot penetrate). However, a more serious threat to the ABL's effectiveness is its own vulnerability to other DE weapons. Weight and volume requirements may preclude fighter-sized aircraft from carrying long-range DE weapons, but those requirements are greatly relaxed for ground-based systems.

Operation from the high ground represents a major factor in the ABL's effectiveness. High-altitude operations provide the line of sight needed for extended range and put the weapon above much of the atmosphere and associated weather, reducing beam distortion and attenuation. That same high ground, however, also puts the ABL in the line of sight of DE weapons on the ground. Speed-of-light propagation makes for a formidable ground weapon despite the limitations of atmospheric attenuation and the horizon on a ground weapon's range and line of sight. Overcoming atmospheric effects to extend the effective range of a ground weapon may prove as simple as scaling up its size or deploying an array of weapons to focus multiple beams on a distant target. Once a target is in range, the effectiveness of a ground-based DE weapon depends only on detection and aiming since the weapon's effect is essentially instantaneous over usual ranges.[23] Using networked information from sensors that can see over the horizon to cue the weapon should allow an assured kill as soon as the target breaks the horizon.

The deployment of practical laser weapons raises fundamental questions for Airmen. Can any aircraft operate within range of a DE weapon? Is the F-22 the "last-generation" fighter? How do we attack a weapon that can destroy incoming missiles and warheads? How do we achieve air superiority against an enemy with ground and airborne lasers? The task of rolling up enemy air defenses remains, but the individual targets are now much tougher.

We have no experience with these weapons in combat—only questions. However, we would do well to remember past revolutions in weapons technology: "distance" weapons (English longbows) against "contact" weapons (French mounted knights) at Crécy and Agincourt, and machine guns against unprotected cavalry and infantry in World War I. Tactics and doctrine adjusted to accommodate these changes, but it wasn't pretty.

2010 Is Today

The changing nature of CAS, autonomous combat UASs, and DE weapons do not change the fundamentals of warfare. They do, however, provide new tools that we must learn to use or counter. The key is not the system itself—but what we can do with the system. We are seeing rapid advances in UAS operations driven by the pressure of combat in Iraq and Afghanistan. Without that pressure, and without their successful debut over Kosovo in the 1990s, UASs would likely remain curiosities confined to the lab or occasional field experiments.

With each new technology comes a fundamental question—what can we do with it? The metric for the answer is simple but context dependent: for what missions or situations is the new technology better, and when is it just different?

Our challenge today is more traumatic than the decision to embrace an "all-jet" Air Force. We are not merely swapping a spinning propeller for a tail of fire. As UASs and other new weapons demonstrate capability, they become alternatives—not additions to or adjuncts of the manned force. Much of the stress on the current budget comes from the cost of maintaining the old capability (whether through extending the service life of old systems or developing better versions) while beginning to acquire the new. At some point, we must reduce our reliance on horse cavalry (the A-10/F-35?) and embrace the mechanized brainpower of a UAS force. ❑

Notes

1. See Grant T. Hammond, *The Mind of War: John Boyd and American Security* (Washington, DC: Smithsonian Institution Press, 2001).

2. Air Force Doctrine Document (AFDD) 2-1.3, *Counterland Operations*, 11 September 2006, 6, http://www.fas.org/irp/doddir/usaf/afdd2-1-3.pdf.

3. Robert Waal, "Keeping Watch," *Aviation Week and Space Technology* 169, no. 18 (10 November 2008): 53.

4. For a discussion on the current demand for CAS, see Rebecca Grant, "Armed Overwatch," *Air Force Magazine* 91, no. 12 (December 2008): 40, http://www.airforce-magazine.com/MagazineArchive/Pages/2008/December%202008/1208overwatch.aspx.

5. AFDD 2-1.3, *Counterland Operations*, 58.

6. Jeffrey Kappenman, "Army Unmanned Aircraft Systems: Decisive in Battle," *Joint Force Quarterly*, issue 49 (2nd Quarter 2008): 20–23, http://www.ndu.edu/inss/Press/jfq_pages/i49.htm.

7. The system's range exceeds 40 nautical miles. See "GBU-39B Small Diameter Bomb Weapon System," US Air Force fact sheet, http://www.af.mil/factsheets/factsheet.asp?fsID=4500 (accessed 15 December 2008).

8. The wind-corrected munitions dispenser, extended range, has a range of 40 miles, providing standoff precision delivery for this weapon as well. See Susan H. H. Young, "Gallery of USAF Weapons," *Air Force Magazine* 91, no. 5 (May 2008): 158–59, http://www.airforce-magazine.com/MagazineArchive/Pages/2008/May%202008/May2008.aspx.

9. John A Tirpak, "Washington Watch," *Air Force Magazine* 91, no. 11 (November 2008): 12, http://www.airforce-magazine.com/MagazineArchive/Pages/2008/November%202008/1108watch.aspx. In September 2008, the Army and Air Force reached an agreement on a joint concept of operations for unmanned aerial vehicles (UAV), which gives the Air Force control of all high-altitude operations while allowing the Army to control tactical operations below 10,000 feet. The Army operates Sky Warrior UAVs—armed variants of the basic Predator, similar to the MQ-1. Details should be finalized in early 2009, but the basic principle clears the way for the Army to extend its organic CAS capability from helicopter gunships to include UAVs.

10. Kenneth P. Werrell, *The Evolution of the Cruise Missile* (Maxwell AFB, AL: Air University Press, September 1985), 16, http://handle.dtic.mil/100.2/ADA162646 (accessed 15 December 2008).

11. Ibid., 32.

12. Lt Col E. J. Kellerstrass, "Drone Remotely Piloted Vehicles and Aerospace Power," *Air University Review* 24, no. 6 (September–October 1973): 44–54, http://www.airpower.au.af.mil/airchronicles/aureview/1973/sep-oct/kellerstrass.html (accessed 31 January 2009).

13. "From the A300 to the A380: Pioneering Leadership," *Airbus*, http://www.airbus.com/en/corporate/innovation/ (accessed 15 December 2008). The European Airbus family of aircraft had an autoland capability as early as 1977.

14. "30 Years of Aerospace Technology," *NASA Tech Briefs*, 1 October 2006, http://www.techbriefs.com/component/content/article/901?start=1b (accessed 15 December 2008). Airbus's latest aircraft, the A380, is equipped with an Autopilot Traffic Collision Avoidance System, linking this function to the autopilot and "Brake-to-Vacate" technology. This allows pilots to select an appropriate runway exit when landing and regulate the aircraft's speed and deceleration accordingly.

15. Guy Norris, "Pilot Optional—US Army Quietly Tries Caravan UAV Out for a New Defense Role," *Aviation Week and Space Technology* 169, no. 19 (17 November 2008): 38.

16. Twenty-two thousand miles up to and 22,000 miles down from geosynchronous orbit + some distance of surface relay / 186,000 miles per second (speed of light) = .24 seconds one-way signal travel time. Two-way transmission will take twice that amount of time plus the time for the operator to react to the information.

17. MSgt Joy Josephson, "The 'Hog' Drops in on History," *Air Force Link*, 14 November 2008, http://www.af.mil/news/story.asp?id=123124172&page=3 (accessed 15 December 2008).

18. For an excellent overview of the Predator acquisition saga, see Michael R. Thirtle, Robert V. Johnson, and John L. Birkler, *The Predator ACTD: A Case Study for Transition Planning to the Formal Acquisition Process*, RAND Report MR-899-OSD (Santa Monica, CA: RAND National Defense Research Institute, 1997), http://www.rand.org/pubs/monograph_reports/MR899/ (accessed 15 December 2008).

19. "Boeing Airborne Laser Team Fires High-Energy Laser through Beam Control System," news release, Boeing, 1 December 2008, http://www.boeing.com/news/releases/2008/q4/081201a_nr.html (accessed 15 December 2008).

20. "Since the weapon system was designed to shoot down theater ballistic missiles, will it have enough power to shoot down the longer-range missiles? Yes. The COIL [chemical oxygen iodine laser] is a megawatt-class laser, which means in its current configuration of six modules it is designed to generate a million watts or more of energy to destroy a target at a distance of more than 200 miles." Airborne Laser System Program Office, Office of Public Affairs, "The Airborne Laser: Frequently Asked Questions," US Air Force fact sheet, 24 March 2003, http://www.kirtland.af.mil/shared/media/document/AFD-070404-024.pdf (accessed 15 December 2008).

21. David A. Fulghum, "Gates's Opening: Defense Secretary Turns to Procurement Cleanup," *Aviation Week and Space Technology* 169, no. 22 (8 December 2008): 26.

22. The ABL system uses a tracking laser to aim the weapon's beam, potentially allowing for some warning before a shot. More conventional surveillance and targeting radars that may be needed for other DE weapons can also provide some warning of attack. However, this warning would be orders of magnitude shorter than the time between detecting a missile's guidance lock-on or launch and the arrival of that missile at the target.

23. Another simple calculation shows that at light speed—186,000 miles per second (300,000 kilometers per second)—the beam reaches a target 200 miles away in .001 second.