Our review and qualitative and quantitative analyses of past air operations and future projections identified those mission areas in which existing DC2BM capabilities are assessed to be adequate and those in which shortfalls exist. Not surprisingly, since we focused on dynamic operations, our analyses suggest that the performance of systems (C2BM, ISR, aircraft, and weapons) in each of the mission areas would benefit to some extent from improvements in the six identified DC2BM functions.

In this chapter, we summarize DC2BM shortfalls for four mission areas and suggest actions for improving DC2BM. The mission areas examined are (1) counterair operations, focusing on cruise missile threats; (2) theater missile defense (TMD), focusing on counterforce operations against transporter-erector-launchers (TELs); (3) suppression of enemy air defenses (SEAD) in the context of strike missions against targets defended by advanced air defenses; and (4) interdiction operations, focusing on small-unit ground forces intermingled with the civilian population.

COUNTERAIR OPERATIONS

The concept of dynamic command and control and battle management is not new to the U.S. Air Force: Counterair operations routinely rely on DC2BM. In fact, nowhere is DC2BM more critical than in the area of air-to-air engagements, where the speed of operations dictates close coordination among the various air defense elements in order to effectively, efficiently, and rapidly defeat the enemy air threat.
Along with SEAD, the Air Force conducts counterair operations to achieve and maintain air superiority and supremacy. Both offensive counterair (OCA) and defensive counterair (DCA) operations are conducted to neutralize all enemy air threats, including fixed and rotary-wing manned combat and reconnaissance aircraft, unmanned aircraft (such as cruise missiles and unmanned aerial vehicles), and ballistic missiles.

We examined the capabilities of the United States to defend against conventional military aircraft (fighters, bombers, and helicopters) by reviewing the results of past military operations (Desert Storm and Allied Force). Combat identification continues to be an issue, primarily because of limitations in sensor systems and identification friend or foe (IFF) systems. Such limitations can result in a requirement for visual confirmation of the air or ground target by the shooter, which can put the shooter at greater risk. Except for such concerns, the U.S. Air Force is well-equipped and well-trained from a DC2BM perspective to conduct counterair operations against a conventional military aircraft threat posed by likely future adversaries in major theater wars and lesser-intensity conflicts.

Counterair operations, however, may be less effective in the future because of the likely proliferation of cruise missiles. Cruise missiles are considered to be a low-cost solution for theater strike. Their small
size can make them difficult to defend against (if the missiles are air-launched, they also enhance the survivability of the manned aircraft that launch the missiles outside defended airspace). Further, the United States has demonstrated the military effectiveness of cruise missiles for theater strike. Finally, cruise missiles pose a significant new security challenge if armed with chemical, biological, or nuclear weapons of mass destruction (WMD).

Although existing DC2BM capabilities are adequate for counterair missions against conventional aircraft, our analyses suggest that successful DCA barrier operations against cruise missiles will require several enhancements to the current DC2BM process. These enhancements would also improve operations against conventional military aircraft. Some of the enhancements are programmed or planned; others require further study. We grouped them into three categories: situational awareness, networked communications, and defense in depth.

Situational Awareness. Good situational awareness and an accurate air picture are needed by the Airborne Warning and Control System (AWACS) aircrew to support effective and efficient air-to-air engagements in a crowded airspace that contains coalition military aircraft (both conventional and stealthy) as well as enemy cruise missiles. These attributes are essential to ensure airspace control, deconfliction, and efficient allocation of interceptors to air targets. The mission crew commander’s guidance and direction are essential in building an accurate air picture and establishing good situational awareness. His guidance and direction establish cross-correlation requirements and identification thresholds to classify air contacts.

5A very advanced cruise missile threat would present a serious challenge to the Air Force. In addition to DC2BM enhancements, a new airborne sensor system with more power and a larger aperture (presumably, a phased-array antenna) would be needed to counter the missile’s low radar cross section (Hura, McLeod, et al., 2001). An unmanned variant is also a possibility. Alternatively, a space-based system could be developed, if cost-effective. A new, manned airborne system would rely on DC2BM concepts discussed here; however, an unmanned airborne system or a space-based system, with the sensors separate from the C2BM functions, would require new concepts not addressed in this study.

6Good situational awareness and an accurate air picture will also support dynamic tasking (including route deconfliction) of fighters against ground TCTs.
Counterair operations normally require a rapid response to engage imminent air threats. This is particularly true for low-observable air targets such as cruise missiles; given the shorter detection ranges, there is less time to react. However, without an accurate air picture, commanders will rely on restrictive rules of engagement to minimize the chances of fratricide. Specifically, the AWACS mission crew commander or his designate will not have the necessary authority to declare air threats “hostile” and to direct airborne interceptors to engage them (i.e., to authorize weapons release). This was a major issue during Operation Allied Force.

Because of the importance of the counterair mission to the Air Force, that service should play a major role in developing capabilities for creating and maintaining an accurate air picture.7

An important attribute of an accurate air picture is that it should depict all air traffic in the theater of operations. As U.S. stealth assets and airborne reconnaissance assets such as unmanned aerial vehicles (UAVs) increase in number, it becomes more critical to find a method to incorporate them into the air picture. It is even more critical if these airborne reconnaissance assets deviate from their flight plans, for example, to collect information on a ground TCT. Civil air traffic and commercial air traffic can also be a source of confusion, especially if aircraft deviate from planned flight paths.

Increasing the detection range of AWACS will also improve situational awareness. The AWACS Radar System Improvement Program (RSIP) provides a factor-of-two improvement in detection range against low-observable targets;8 complete implementation on AWACS is planned to be completed during 2005.9 Another programmed improvement is the addition of Integrated Broadcast Ser-

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7 After this research was completed, the authors learned that senior DoD officials signed a charter on October 26, 2000, for a new joint-service task force that will identify the most effective and efficient means for building and maintaining a single integrated air picture that satisfies the warfighters’ needs (Dupont, 2000). The Navy is the lead systems engineer, the Air Force is the deputy lead engineer, and the Army is the acquisition executive.

8 ACC, 1996, p. 82.

9 Air Combat Command announced initial operational capability (IOC) on June 14, 2001, with seven RSIP-equipped AWACS. Work on the remaining 25 AWACS is expected to be complete by February 2005 (Mayer, 2001).
vice receivers to ensure access to information collected by theater and national reconnaissance assets; receivers have been purchased and installation on AWACS has begun.

Upgrades to AWACS computers and displays would also improve the air picture. Specifically, a new tracker, improved IFF capabilities, and integration and fusion of onboard and offboard sensor data (e.g., multisensor integration) are needed to improve tracking and identification, and an improved graphical user interface technology (e.g., man-machine interface) is needed to reduce C2BM process timelines. The Air Force is planning to acquire these upgrades (under Block 40/45) when funding becomes available.

**Networked Communications.** Tactical digital information links (TADILs) offer network participants a number of advantages over voice communications. A wide range of combat data in addition to voice can be shared over a secure, jam-resistant communications network that is continuously and automatically updated. Data can be sent faster and more reliably via direct digital (i.e., computer-to-computer) communications, and text messages need only a small fraction of the communication resources that interactive voice messages require.

A number of TADILs have been developed to support near-real-time exchange of data among tactical data systems. The most recent is Link 16. Link 16 is an encrypted, jam-resistant, nodeless tactical digital data link network established by Joint Tactical Information Distribution System (JTIDS)–compatible communication terminals that transmit and receive data messages in the TADIL J message catalog.

In counterair operations, AWACS weapons directors must relay timely and accurate threat data to airborne interceptors, preferable via a tactical digital data link (such as Link 16) rather than secure voice communications. In addition, a data link will improve coordination among the participants of the counterair operations. In particular, situational awareness would be enhanced among network participants by the network’s automatic and continuous update of friendly tracks as well as tracks of hostile aircraft.

AWACS, Rivet Joint, ground C2 centers, and one squadron of F-15Cs already are equipped with Link 16 terminals (specifically, JTIDS terminals). The Air Force plans to equip the rest of its fighters (F-16s,
F-15C/Es) with Link 16 terminals (specifically, Multifunctional Information Distribution System terminals).

Other networked communications may be needed to support defense in depth, as discussed in the next section.

**Defense in Depth.** Although not explicitly examined because our focus was on DCA barrier operations, we believe that a multilayer defense construct would improve defense effectiveness against cruise missiles and is probably needed against stealthy variants. The Air Force should develop DC2BM CONOPS and capabilities for engaging cruise missiles and other stealthy aircraft that include defense in depth.\textsuperscript{10}

In particular, procedures and systems for disseminating guidance and orders and sharing of sensor data and information from one layer to the next are essential. Thus, fighters conducting OCA sweeps (e.g., F-22s) should relay cruise missile detections and results of engagements to AWACS supporting DCA barrier operations. Currently, F-22s are planned to have a receive-only Link 16 capability when the F-22 program reaches initial operating capability in December 2005, to support their OCA operations. This is perceived as a shortfall for defense-in-depth operations (F-22 could use secure voice communications to provide some situational awareness back to AWACS).\textsuperscript{11}

Similarly, AWACS should relay data and directions (if assigned authority) on cruise missile leakers of barrier operations to terminal area and point air defenses. This could occur via a joint data network (JDN) such as Link 16 (both the Army and Navy have or are acquiring Link 16 capabilities), or via a joint composite tracking network (JCTN) such as the Navy’s Cooperative Engagement Capability

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\textsuperscript{10}Another defense-in-depth construct, one for theater ballistic missiles, is discussed in the next section. The defense-in-depth construct for engaging aircraft and cruise missiles should be combined with that for theater ballistic missiles to create an overall joint theater air and missile defense construct.

\textsuperscript{11}After this research was completed, we learned that the Air Force believes that it will be able to field Link 16 transmit capability for the F-22 in about 2007 in the aircraft’s first post-IOC software upgrade (Wolfe, 2001).
In all likelihood, both will be used by terminal defenses. Thus, interfaces between JCTN and JDN will be needed.

**THEATER MISSILE DEFENSE**

Allied experience with Iraqi mobile Scud theater ballistic missiles (TBMs) has led to increasing emphasis on systems and operational concepts for dealing with mobile, time critical targets of this sort. In fact, for a number of years, the Scud’s TEL was the prototypical TCT.

Shortfalls in ISR, C2BM, and weapon systems contributed to the Allies’ poor performance against TBMs during Operation Desert Storm. Since then, DoD has responded with a number of initiatives to improve U.S. capabilities against this threat. Because no single defense element can provide the desired level of performance (near-zero leakage), especially against TBMs armed with WMD, there has been substantial emphasis on developing a multilayer defense capability (i.e., defense in depth) for TMD.

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12 JDN and JCTN are two of the three communication network constructs defined by the Joint Theater Air and Missile Defense Organization (JTAMDO) (the third is the joint planning network [JPN]). A JDN is a collection of near-real-time communications and information systems that permits ground, air, and sea controllers to provide (and exchange) ISR and C2 information to shooters. A JDN carries near-real-time tracks, unit status information, engagement status and coordination data, and force orders. Among other data, it provides the identification, location, heading, speed, altitude, and status of friendly aircraft, missiles, ships, submarines, and selected ground systems; and the location, heading, speed, altitude, and (if available) the identification of neutral and enemy air, sea, submarine, and ground contacts. A JCTN is a real-time sensor fusion system that enables ships, aircraft, and ground air defense systems to exchange sensor measurement data to create common composite air tracks of fire control accuracy. It includes common software and a communication element that allow participating units to share and fuse real-time sensor data.

13 This is not a trivial task; the Navy has experienced problems integrating Link 16 and CEC on its Aegis ships.

14 More specifically, the Scud TEL was the Soviet MAZ 543.

15 Defense in depth provides multiple shot opportunities against difficult targets such as TBMs, and is a recognized concept within the defense community. It is one of the four basic operational objectives for a joint theater air and missile defense capability. The other three are single integrated air picture; early detection, classification, and identification; and 360-degree coverage (JTAMDO and BMDO, 1998, pp. 2-10 to 2-13).
In our analysis, we focused on Air Force counterforce operations against the TELs—both prelaunch and postlaunch operations—and the necessary DC2BM to support these operations. Counterforce operations, to the extent that they can be successful, clearly benefit the other elements of the TMD defense-in-depth architecture by reducing the number of missiles and the salvo potential that other defense elements (boost phase, midcourse, terminal, and passive defenses) will have to counter. If the enemy’s TELs can be systematically destroyed, fewer missiles will be launched, resulting in fewer missiles to be countered by the next defense layers and hence in less damage to friendly forces and population. In the limit, if the number of TELs is small compared with the number of reload missiles, killing all the TELs, even postlaunch, can ground reloads. Given the current expense and complexity of TELs, it would be expected that the number of reloads per TEL might be quite high.

Our analysis shows that current DC2BM capabilities are inadequate to support prelaunch and postlaunch counterforce operations against TBM TELs. Improvements in all six DC2BM functional areas are essential to ensure that the DC2BM process is completed in the tight, threat-driven timelines—with timelines approaching 10 minutes or less, measured from the time of initial detection of a possible TCT to order issuance to a strike aircraft.\(^\text{16}\) Moreover, TMD-related DC2BM initiatives should initially focus on postlaunch counterforce operations since this mission is best supported by existing ISR capabilities.

We use the following four categories for our discussion of potential improvements: new sensors and sensor upgrades, fighter sensor upgrades, dynamic C2BM processes and tools, and collaborative environment and networked communications.

**New Sensors and Sensor Upgrades.** As with most TCT challenges, solutions to TMD counterforce problems will require significant improvements in our ISR capabilities. Because of the depth and operational flexibility inherent in long-range TBM threats, the United States will require new sensors and sensor platforms. These must address the serious challenges of providing affordable and militarily

\(^{16}\)This timeline does not include the flight times of retasked sensor(s) and strike aircraft to possible targets.
useful capabilities, including deep-look, long-dwell, all-weather/day-night operations, and acceptable survivability in the face of advanced air defenses. For postlaunch operations, focused-look surveillance capabilities are sufficient, whereas for prelaunch counterforce operations, broad-area search with much higher search rates at higher imagery resolution (relative to existing capabilities) is needed. These advanced capabilities will be needed in peacetime, day-to-day, for intelligence and strategic warning; in short-notice crises; and in war.

Upgrading existing sensor systems also offers promise for scenarios in which standoff sensor platforms can surveil the deployment areas or in which air defenses have been sufficiently suppressed to allow increased penetration by sensor platforms. For example, planned and proposed upgrades for Joint Surveillance [and] Target Attack Radar System (JSTARS) should improve the platform’s ability to detect, identify, and track stationary and moving vehicles. The upgrades include (1) integration of the advanced radar being developed under the Multi-Platform Radar Technology Insertion Program (MP-RTIP), which will significantly shorten the revisit rate over the ground radar coverage area; (2) development of better tracking algorithms to improve the chances that identified targets will be continuously tracked until an attack asset arrives; (3) development of better ground moving target indication (GMTI) discrimination capabilities beyond the double-Doppler wheeled/tracked distinctions—for example, a high range resolution (HRR) GMTI radar mode and associated algorithms that can exploit the collected range profiles; (4) development of an all-source integration capability to aid in understanding TBM/TEL operations and identifying targets—for example, the target evidence accumulator; (5) development of improved imagery geolocation capabilities—for example, JSTARS Imagery Geolocation Improvement (JIGI);\(^1\) and (6) integration of appropriate TADIL J messages to support ground attack (i.e., JSTARS Attack Support Upgrade program). Many of these capabilities could also be applied to alternative aircraft platforms, such as high-altitude en-

\(^1\)JIGI is an Air Force Tactical Exploitation of National Capabilities initiative. It is a stand-alone workstation that correlates JSTARS data with geocoded archival national imagery to improve the geolocation accuracy of detected tactical targets.
durance UAVs (e.g., Global Hawk) or a new multimission C2ISR aircraft.\(^{18}\)

While such sensor and data exploitation upgrades will improve the capabilities of existing manned platforms to support missions such as TMD counterforce, the high-value platforms themselves have deficiencies (e.g., in survivability, access, responsiveness, operations tempo) that may limit their effectiveness for these challenging counterforce missions, even with improved sensor and processing systems. Consequently, it is important to build in as much adaptability and scalability as possible in these sensor advances to support their future application in other platforms (e.g., stealthy UAVs and satellites).

**Fighter Sensor Upgrades.** Sensor upgrades may also be appropriate for the fighters, as well, depending on the specific operational concept (e.g., the extent to which the fighters can rely on offboard targeting [for instance, receiving coordinates for Joint Direct Attack Munition employment] versus having to find, track, identify, and target the TELs themselves based on relatively crude offboard cues). For example, improving the resolution of the F-15E’s APG-70 in the synthetic aperture radar (SAR) mode, adding a GMTI capability, providing the ability in the air-to-air mode to track (and, hence, backtrack) inflight ballistic missiles, and sensor management aids to improve area search may all be worthwhile improvements for the TMD counterforce mission (and are likely to be possible with relatively inexpensive software modifications). Further in the future, initiatives such as the Advanced Targeting Pod may be critical in improving the shooters’ ability to engage these targets under a variety of challenging operational conditions.

**Dynamic C2BM Processes and Tools.** Improvements in C2BM capabilities are also needed. For example, decision aids, based on

\(^{18}\)During the course of our analysis, the commander of Air Combat Command published a proposal advocating a multimission aircraft (MMA) that would be used to support the Expeditionary Air Force more fully, incorporating capabilities of AWACS, JSTARS, Rivet Joint, and the Airborne Battlefield Command and Control Center (ABCCC), and adding an airborne information fusion functionality (Jumper, 2001). In addition, the AC2ISRC is developing an operational concept for multimission C2ISR aircraft (AC2ISRC, 2000d). More recently, the AC2ISRC concept has furthered evolved into the multisensor command and control aircraft (MC2A) (AC2ISRC, 2001).
game-theoretic analysis that explicitly evaluates the outcomes of two-sided games with alternative Blue and Red strategies,\textsuperscript{19} may be valuable in supporting responsive, rationalized force allocation decisions by combat plans staffs. As U.S. TMD capabilities are developed and fielded, potential adversaries will respond. The analysis of these action/reaction cycles (using, for example, simple tools from game theory) is critical to determine the most profitable strategies for the United States to adopt. An effective TBM defense posture will most likely involve defense in depth, which includes prelaunch and postlaunch counterforce operations and active and passive postlaunch defenses.

Combat operations will also need enhancements to support prelaunch and postlaunch counterforce operations. The result of these enhancements should be measured in terms of very short C2BM timelines (approaching 10 minutes or less). The Air Force should work to achieve the technical, cultural, and organizational changes that will make this improvement possible. Perhaps most important is the development of a TCT functionality that includes TTP, personnel, and systems for (1) developing a good IPB, (2) maintaining an accurate, near-real-time, integrated air and ground situational awareness; (3) performing rapid target development and nomination; (4) performing rapid weapon and target pairing; (5) ensuring rapid decision and order issuance; and (6) ensuring timely dissemination of information necessary for mission execution and assessment.

The development of necessary TCT functionality in the short term should concentrate on the postlaunch counterforce problem, where improvements are likely to come most readily, but should also include elements that will facilitate the integration of all phases of TMD operations.

**Collaborative Environment and Networked Communications.** To accomplish these functions in times approaching 10 minutes or less, a robust collaborative environment is needed that includes automated tools; on-demand, high-data-rate communications; a robust network and server architecture with responsive operating protocols;

\textsuperscript{19}Examples of such analyses are given in Hamilton and Mesic, 2001, and Hura, McLeod, et al., 2002, Appendix B.
an expert network manager; and an expert and empowered information manager. Further extensive automation of data management and applications to assist operators perform the DC2BM functions is essential.

SUPPRESSION OF ENEMY AIR DEFENSES

SEAD is a critical mission area because its success or failure has a significant impact on all air operations and supported ground operations. SEAD has two objectives: to minimize friendly aircraft attrition and to maximize air power flexibility and effectiveness. Threat avoidance is the preferred doctrinal means for minimizing aircraft attrition. This is usually accomplished by route planning, stealth, and standoff weapons. In those instances when threat avoidance is not a viable option (e.g., when threat locations are poorly known) or the demands of the military effort require the threat to be overcome to maximize air power flexibility, effectiveness, and support to ground operations, suppression or destruction of the threat is necessary.

Military operations during the 1990s clearly showed that U.S. air forces can help win the war while concurrently maintaining very low levels of aircraft losses in the face of most currently deployed air defenses of likely adversaries. The combination of threat avoidance, judicious tactics, self-defense capabilities, and suppression packages (e.g., jamming aircraft, aircraft carrying anti-radiation missiles, air-launched decoys), and associated DC2BM has been effective against older generation surface-to-air missiles (SAMs).

However, these successes have not been without considerable costs and risks. SEAD requires significant allocation and application of forces (aircraft and people), increases organizational strain, and limits preferred attack CONOPS. Low-level air operations, in particular, have been hampered by an inadequate ability to detect, locate, identify, track, and target anti-aircraft artillery and man-portable infrared-guided and electro-optical-guided SAMs and anti-aircraft artillery. This has been a persistent ISR shortfall and we do not offer an ISR solution here. Existing workarounds to deal with these threats suggest a continued focus on DC2BM efforts that support threat avoidance, judicious tactics, and self-defense measures.
Successful air operations are expected to be further challenged if future adversaries deploy more-capable air defense systems, such as the SA-10 and SA-20. The worrisome trends associated with these emergent threats include increased range, lethality, mobility, and netting (i.e., development of an integrated air defense system).

The expected performance of these advanced air defense systems places current CONOPS and weapon systems at increased risk and will require improvements in all aspects of the engagement process. Responses to such emergent threats will likely involve a mixture of improvements to ISR systems, C2BM capabilities, weapon systems, and communications. We use the following four categories for our discussion of potential improvements: situational awareness and new sensors, dynamic C2BM processes and tools, new weapons, and networked communications.

**Situational Awareness and New Sensors.** Situation awareness in an environment with advanced SAM systems is critical. It must be timely and accurate, providing knowledge of threat location, tactics, and strategy to both strike aircraft and SEAD platforms. Improved signals intelligence systems are needed that can operate across the entire signal spectrum and that can quickly identify and accurately locate emitters that operate intermittently. There will be increased emphasis on, and requirements for, ISR sensors that can surveil mobile targets until weapon systems achieve target destruction. Specifically, there is a need for focused-look, long-dwell imaging sensors capable of operating day and night in unfavorable weather conditions while surviving in a severe threat environment. Without these capabilities, U.S. military forces cannot effectively detect, locate, identify, track, target, and engage advanced SAMs.

**Dynamic C2BM Processes and Tools.** More-dynamic C2BM systems, procedures, and CONOPS are needed to shorten response times so that mobile SAMs can be killed before they flee. Automated tools and procedures are needed for rapid retasking of sensors and associated PED, and for processing and correlation of information from multiple intelligence disciplines (i.e., multi-INT fusion). Decision aids are also needed to more effectively support the dynamic management of future integrated strike and SEAD packages. These aids should pro-
vide needed functionality in the air (e.g., air command element, C2ISR package commander\(^{20}\)) and on the ground (e.g., TCT cell or combat operations division in the air operations center [AOC]). SEAD CONOPS must be updated to reflect the need for more-dynamic C2BM procedures. They must also be adapted to incorporate not only future kinetic (explosive) weapon systems but also new nonkinetic information warfare (IW) techniques. Furthermore, these CONOPS must be flexible enough to respond appropriately to variations in enemy air defense strategies ranging from maximum engagement and concomitant friendly-force exposure to episodic engagements with minimal exposure.

Automation can also enhance the Air Force’s ability to dynamically reroute strike aircraft, which should greatly improve strike aircraft survivability and SEAD effectiveness. Although perfect situational awareness is always preferred, the consequences of imprecise, inaccurate, or obsolete information resulting from mobile air defenses can be minimized when inflight updates to strike platforms—including rerouting information—enable aircraft to avoid encounters or at least minimize their effects. Supported by appropriate communications, autorouting tools will also enable strike aircraft to respond to the dynamics of SEAD operations.\(^{21}\)

**New Weapons.** Although necessary, the improved ISR and C2BM capabilities discussed above are not sufficient. SEAD weapon systems also need increased stealth, range, and lethality. The fielding of stealth aircraft and longer-range standoff weapons allows the Air Force to strike targets with minimum exposure time in the lethal range of enemy air defense systems. But these weapons must be cued. Cueing calls for enhanced DC2BM capabilities that support

\(^{20}\)The C2ISR package commander is a new concept that is an outgrowth of identified needs in exercise, experiment, and operational situations. A formal C2ISR package commander course is being taught at the AWACS wing and was showcased for the first time during the Red Flag exercise held at Nellis AFB during January–February 2001. The C2ISR package commander would be responsible for orchestrating all of the C2, ISR, and electronic support assets executing in the joint force air component commander’s tactical area of responsibility (552nd ACW, 2000).

\(^{21}\)Note that autorouting tool development will expand flex targeting opportunities for targets other than air defenses. Allied Force flex targeting was limited in its success, and one of the reasons was the inability of most of the force to be dynamically rerouted and mission planned.
rapid retargeting of new standoff weapons. In addition to kinetic weapons, electronic warfare and innovative IW methods will likely be required to combat netted air defense systems.

**Networked Communications.** Finally, to better support current SEAD CONOPS and enable future integrated strike/SEAD CONOPS in the presence of advanced air defenses, development of networked communications should be continued. Current programs for improving communications, such as Link 16, Improved Data Modem, and various gateways should be synchronized (through interoperable systems or via gateways), and new capabilities fielded as technologies allow.

**INTERDICTION**

Air interdiction or battlefield air interdiction, herein simply “interdiction,” is performed by the Air Force to help shape the battlefield, to attrit hostile forces, and to disrupt enemy lines of communication and logistics support. Typically, interdiction missions have been flown in support of joint air-land campaigns. Operation Desert Storm and subsequent interdiction campaigns, however, have deviated somewhat from this combined-arms model.

**Large Armor Formations**

Interdiction during the halt phase of a major theater war remains a critical military mission to minimize the territory captured by an invading army and to protect forces currently in theater. The mission is particularly challenging because the targets are mobile, hard to kill, and defended by fixed and mobile SAMs and anti-aircraft artillery. It

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22Improved Data Modem is a high-speed digital data link modem that is an interface between the aircraft’s onboard radios (HF, UHF, VHF, or satellite communications) and its mission computer. It can pass near-real-time mission and targeting data among ground-based observers, military aircraft, attack teams, and artillery fire direction centers. The system is fielded on select Air Force aircraft, such as Rivet Joint, JSTARS, and F-16 Block 40 and Block 50. It is also fielded with tactical air control parties and at air support operations centers.

23Gateways are devices that support information exchange between a variety of communication systems to ensure the rapid exchange of information among C2BM nodes and between these nodes and attack assets.
becomes even more challenging in a short-warning scenario that quickly leads to open hostilities and necessitates the rapid deployment of additional forces to theater.

Recent RAND analyses\(^\text{24}\) of a postulated Southwest Asia scenario indicate that current and planned programs (sensors, C2BM, and weapons) will maintain the effectiveness of interdiction assets against ground forces in large formations. However, improvements in two areas (sensor and battle management upgrades and networked communications) could improve efficiency.

**Sensor and Battle Management Upgrades.** A number of planned and proposed JSTARS upgrades—MP-RTIP, a better tracking algorithm (e.g., kinematic automatic tracker), better GMTI discrimination capability (e.g., HRR), a multisource integration/fusion capability (e.g., target evidence accumulator), imagery geolocation improvements (e.g., JIGI), and updates to the TADIL J message set (i.e., the Attack Support Upgrade program)—should increase efficiency of interdiction operations.\(^\text{25}\) Another useful improvement is a decision aid to support targeting, especially for standoff weapons; this tool would rely on the information provided by many of the above initiatives.

As discussed in the previous sections, these improvements have broad applicability to other airborne platforms (e.g., UAVs) and across a number of mission areas. In fact, they are critical capabilities for TMD and SEAD. Moreover, these improvements should be developed so that they can be integrated into ground C2BM facilities that control future UAVs and space-based radars.

**Networked Communications.** Finally, in the near term, networked communications systems are expected to provide connectivity for ground and airborne C2BM nodes and strike aircraft. In particular, Link 16–coordinated operations could significantly improve the flow of strike assets in situations where large formations of armor are attacking.

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25These JSTARS upgrades also apply to TMD and were described in more detail in the TMD section of this chapter.
Small-Unit Ground Forces

Traditionally, the Air Force has focused on the interdiction of large armor formations as a key mission and has devoted less attention to air-to-ground operations against small-unit ground forces. Over the past ten years, however, it has attempted to use air power against such forces. Air operations against small-unit ground forces are particularly difficult when a corresponding friendly ground component is not available to help detect, track, and identify targets on the ground, and then to assess the results of air-to-ground engagements. As demonstrated in Operation Allied Force and other recent operations, C2BM for the interdiction of small-unit ground forces has been poor for a number of reasons, including difficulties with positive identification of potential targets and with collateral damage assessment. Improvements in three areas (situational awareness, decision aids, and joint CONOPS) could help remedy deficiencies.

Situational Awareness. An integrated air and ground picture should be developed jointly by the services. Such a solution would support the need for positive identification of forces that are intermingled with the civilian population. Because this function is performed primarily with ground sensors and may be much more difficult with air or space sensors, involvement by the Army and special operations forces is essential (however, in certain hostile environments, their employment may not be worth the risk). Making such an integrated air and ground picture timelier requires automated tools to rapidly retask surveillance and identification sensors and provide associated PED.

Decision Aids. Decision tools are needed to help commanders assess the situation, determine collateral damage, recommend response options, and support a go/no go decision.

Joint CONOPS. The Air Force should support improved coordination of the joint force land component commander and joint force air component commander. This can be accomplished through a review and modification of doctrine, CONOPS, and TTP, reinforced through practice and joint exercises.

On the latter issue, our research suggests that developing an operational concept (including TTP, ISR capabilities, and weapon systems) having characteristics comparable to police force operations offers a
reasonable approach for addressing this very difficult mission, at least in low-threat environments or in hostile environments where the benefit outweighs the risk. Such operations typically consist of (1) rationalized surveillance\textsuperscript{26} by remote and in-place sensors (video cameras in banks; foot, car, and helicopter patrols), supplemented by the observation of interested parties (local populace, friendly forces), to detect and report the occurrence of an undesired event (burning of a village); (2) a rapid multiphased response (dismounted and mounted ground and air elements) to contain perpetrators within a small area; (3) high-resolution, small-area sensors to distinguish perpetrators from local populace and friendly forces; and (4) lethal ground and air elements to positively identify and capture or, if necessary, eliminate perpetrators.\textsuperscript{27} To implement such capabilities in military operations requires the close coupling of airborne and ground controllers and decisionmakers in the AOC (as well as ground C2BM nodes of the other services) with air and ground force elements, and automated tools to rapidly perform all six of the DC2BM functional areas.

\textsuperscript{26}Here, \textit{rationalized surveillance} means the optimal allocation of scarce surveillance resources.

\textsuperscript{27}While this concept has been offered as one option for further investigation, differences between the operational situations faced by the police and the military will, in all likelihood, affect the military’s specific implementation and rules of engagement. The nature of the perpetrators is one area of differences. Usually, suspects in police operations are not heavily armed and are interested in escape and evasion (they have already committed the crime) rather than confrontation. Moreover, the police are interested in apprehending suspects for later prosecution, whereas the military may have other more immediate and lethal objectives.