Assessing Airpower's Effects

Capabilities and Limitations of Real-Time Battle Damage Assessment

JOHN T. RAUCH JR., LIEUTENANT COLONEL, USAF
School of Advanced Airpower Studies

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Abstract

This study analyzes how real-time battle damage assessment (BDA) might contribute to airpower strategy and execution. It provides a historical review of BDA during World War II, Vietnam, and the Persian Gulf War and examines the current BDA doctrine, capabilities, and procedures to illustrate contemporary strengths and shortcomings. This study identifies potential remedies to contemporary issues based on real-time BDA solutions by addressing technological, procedural, and organizational aspects. It evaluates the strengths and limitations of these possible remedies, with respect to airpower planning and execution, to identify viable solutions. This study assesses how alternative solutions might affect airpower strategy formation and execution by examining the improvements intelligence agencies and the services are likely to pursue over the near term and concludes with recommendations for the future.

About the Author

Lt Col John T. Rauch Jr. is a senior navigator with more than 2,500 flying hours and has served as lead navigator, instructor, evaluator, and operations group executive officer. He graduated from the University of Colorado at Boulder and received his commission through the Reserve Officer Training Corps in 1989. After graduating from specialized undergraduate navigator training, he flew the RC-135 at Offutt AFB, Nebraska. In 1995 Colonel Rauch was selected for the Air Force Intern Program's inaugural class for tours on the Air Staff in the Intelligence Plans and Legislative Liaison Directorates. He transferred to joint undergraduate navigator training in 1997 and served as flight instructor, training mission commander, student flight commander, and assistant operations officer. He earned a bachelor's degree in Aerospace Engineering from the University of Colorado at Boulder, a master's degree in Organizational Management from George Washington University, and a master's degree in Operational Art and Science from the Air Command and Staff College, Maxwell AFB, Alabama. In June 2002 Colonel Rauch was assigned to Air Education and Training Command as the deputy director of the Commander's Action Group. He is married to the former Diane Botsford, and they have two children: Jack and Kate.

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Chapter 1

Introduction

Victory smiles upon those who anticipate the changes in the character of war, not upon those who wait to adapt themselves after the changes occur.

—Giulio Douhet

Since August 1914 when aviators first dropped bombs on unsuspecting targets to determine how air-dropped munitions affect their targets remains a challenge.[1] Early in World War I, airplanes and zeppelins conducted bombing operations with little feedback on the success of their attacks.[2] However, as air planners needed to determine the effectiveness of prior raids to guide subsequent planning, they began debriefing aircrews and, occasionally, examining photographs taken during the raids.[3] Thus, the precursor of *bomb* damage assessment was born.

The term evolved to *battle* damage assessment (BDA), but the pursuit of precise assessments of air-delivered weapons effectiveness continues. Developers improved the sensor-to-shooter portion of the targeting cycle to satisfy a craving for quicker and more accurate targeting. However, the ability to evaluate the results of an attack has not progressed at the same rate. Furthermore, the acronym *BDA* conjures up different concepts across varying levels of war. At the tactical level, BDA seeks to determine the success of individual missions. On the strategic end of the spectrum, leaders use BDA to ascertain the level of progress in a given phase of war.

Until recently, BDA was not precisely delineated. Following the Persian Gulf War, the Joint Chiefs of Staff defined BDA as the "timely and accurate estimate of damage resulting from the application of military force, either lethal or non-lethal, against a predetermined objective. Battle damage assessment can be applied to the employment of all types of weapon systems (air, ground, naval, and special forces weapon systems) throughout the range of military operations. Battle damage assessment is primarily an intelligence responsibility with required inputs and coordination from the operators. Battle damage assessment is composed of physical damage assessment, functional damage assessment, and target system assessment."[4]

Analysts conduct BDA to determine the answers to an assortment of questions. "Did the weapons impact the target as planned? . . . Did the weapons achieve the desired results and fulfill the objectives and, therefore, purpose of the attack?. . . How long will it take enemy forces to repair damage and regain functionality?. . . Are restrikes necessary to inflict additional damage, to delay recovery efforts, or attack targets not successfully struck?"[5] Analysts and decision makers use BDA to answers these and many more questions.

Statement of the Research Question

It appears that technology may soon enable near-real-time feedback of an attack, either directly to the cockpit or to a site on the ground. Developers are pursuing avenues to deliver this capability to air operations planners and aircrews in the future, and advocates have emerged claiming this capability is the next logical step. How would real-time BDA influence the ways that war fighters develop and execute airpower strategy? This study analyzes how intelligence analysts might achieve real-time BDA and how it might affect airpower strategy development and implementation.

Overview

This study reviews past BDA processes to determine strengths, limitations, and general trends and explores how Airmen used BDA during World War II, Vietnam, and the Persian Gulf War. It reviews the improvements intelligence agencies have made since the Gulf War of 1991. It examines the current BDA doctrine, capabilities, and procedures to illustrate contemporary strengths and shortcomings. With the past and current conditions scrutinized, this study identifies potential remedies to contemporary issues based on real-time BDA solutions; addresses technological, procedural, and organizational aspects; and evaluates the strengths and limitations of possible remedies, with respect to airpower planning and execution to identify viable solutions. This study assesses how alternative solutions might affect airpower strategy formation and execution. It also examines the improvements intelligence agencies and services are likely to pursue over the near term and concludes with recommendations for the future.

Limitations

Although BDA is relevant to warfare in all physical media, this study focuses on the effects of real-time BDA of air-delivered ordnance. Because this study seeks to explore wide-ranging effects, it does not focus on specific platforms. Instead, it concentrates on general concepts for real-time BDA without becoming mired in technological minutia.

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Chapter 2

History of Bomb Damage Assessment

War is not an affair of chance. A great deal of knowledge, study, and meditation is necessary to conduct it well.

—Frederick the Great

To understand most of the contemporary issues surrounding BDA, one only needs to examine how airpower professionals have dealt with them in the past. Airmen repeatedly sought the same things from BDA, and they repeatedly found the same challenges. As weapons became more accurate, air planners needed more detailed information; and as the tempo of warfare accelerated, they needed that information quicker. This chapter examines how Airmen used BDA during World War II, Vietnam, and the Persian Gulf War to identify these trends and offers insight as to why real-time BDA is both desired and difficult.

World War II

BDA was in its infancy during World War II. At the time, intelligence personnel coined the acronym *BDA* for a basic process known as bomb damage assessment.[1] All combatants neglected poststrike analysis in the interwar years, and none developed effective use of aerial photography for intelligence before the outbreak of World War II.[2] During the war, the nature of strategic bombing attacks coupled with the lack of detailed and reliable feedback from the ground led the military to depend on aerial photography to determine the effectiveness of bombing raids. In the spring of 1942, the United States established separate photoreconnaissance units flying modified bombers.[3] The differing geography and levels of enemy threat in various theaters of World War II necessitated using aircraft with diverse characteristics. Consequently, F-5s (modified P-38s) and F-6s (P-51s) were the primary reconnaissance aircraft in Europe; F-7s (B-24s) and F-10s (B-25s) were productive in the Southwest Pacific and the China-Burma-India theaters; and F-13s (B-29s) flew against Japan beginning in November 1944.[4]

The analysis of aerial photography initially developed into two distinct phases: preattack and postattack analysis.[5] Consequently, reconnaissance aircraft flew photographic missions preceding and following attacks.[6] The preattack analysis served to identify the function of an industrial system, locate targets, and reveal battlefield dispositions.[7] These photographs served as a basis for comparison of any subsequent damage assessed against a target.[8] Early during the war in the European theater, postattack analysis summarized the damage assessment in a damage interpretation report.[9] It served three purposes: (1) determined as quickly as possible whether a target required reattack, (2) provided a realistic measure of the success of an effort to inflict damage "rather than the old score board idea expressed in sorties flown and tonnage dropped," and (3) supplied the industrial analyst with information to determine the level of production loss.[10] The Allies centralized these efforts within the European theater in the Central Interpretation Unit, and although this arrangement served the strategic level analysis of industrial attacks well, it proved too slow for operational commanders.[11]

New procedures were required to meet the need for mission feedback and reattack decisions. In Europe organizational constraints made planners wait up to a day for initial assessments and at least 48 hours for final interpretation reports.[12] To reduce the time required for initial BDA analysis, photointerpreters were moved to processing sections at reconnaissance bases to perform tactical analysis based on reconnaissance photos and pilots' reports.[13] The interpreter normally completed and distributed these reports by teleprinter within two hours after the aircraft landed.[14] Similar organizations were at work in the Pacific theater with the Twentieth Air Force's Central Interpretation Unit in Guam conducting basic damage analysis. Meanwhile, the Joint Intelligence Center at Pearl Harbor and the Joint Target Group in Washington, D. C., conducted the most comprehensive analysis.[15]

However, weather conditions could obscure the target for weeks at a time.[16] Consequently, a portion of the American bomber force carried cameras to record strikes in progress to provide feedback to operational commanders.[17] According to one photointerpreter, "The resulting pictures were often unduly gratifying. With fires blazing, buildings collapsing, and smoke obscuring the target, they often suggested greater than actual damage."[18] In an effort to overcome some of these effects, Airmen attempted to develop predictive methods of BDA by taking pictures shortly after bomb release, both day and night, to predict where the bomb load would land.[19]

The demand for fast and accurate damage analysis on extremely important missions led Airmen to develop unique reconnaissance procedures. During efforts against German V-1 sites, a courier hand carried the latest photos and analysis to Gen Carl A. "Tooey" Spaatz under special procedures created for the so-called Dilly Project.[20] Operations in the Pacific theater also necessitated innovative procedures. For the incendiary raid on Tokyo, one of Gen Curtis E. LeMay's best wing commanders remained over the burning city for two hours at 10,000 feet (ft) during the night to estimate the extent of damage for a report upon landing.[21] When Airmen dropped the first atomic bomb on Hiroshima, two other B-29s carrying scientists accompanied the *Enola Gay,* observing and photographing the explosion, in addition to parachuting scientific instruments into the area.[22] These instances illustrate the necessity to work outside the system for important missions and the ingenuity required to overcome system limitations.

After the war, the *United States Strategic Bombing Survey (USSBS)* served to validate the damage assessments developed from aerial reconnaissance photos.[23] Comparing actual to perceived damage on the ground by the photointerpreters firmly established the art of BDA with the *USSBS* as a benchmark.[24] According to the *USSBS*, photointerpreters struggled to assess primary effects and were less successful in determining the secondary effects of bombing raids.[25] This was due in part to the cardinal rule for photointerpreters of "reporting only what could be seen" by another interpreter.[26] Every type of target surveyed contained hidden damage unreported by photointerpreters.[27] For instance, some of the most serious production-related damage to synthetic oil plants, such as broken waterlines and electric cables, often went unnoticed.[28] Interpreters struggled to locate the effects of bombs that exploded well below the roof which left little trace except the hole they passed through.[29] Therefore, analysts often erred to the conservative side on reports when massive craters or obvious damage was not evident from aerial photography.[30] Additionally, it was impossible for them to determine damage to aircraft on the ground at the scale of photos available unless the damage was catastrophic.[31]

Technical limitations of strike photography and a lack of tactical analysis training for photointerpreters made accurate analysis from predictive bomb plotting very difficult.[32] Differences in reconnaissance and strike photograph scales made it hard for analysts to accurately assess damage based on strike photos.[33] Many photointerpreters argued against using strike photos because, as one leading British interpreter stated, "It often took several weeks to obtain truly accurate photographs for analyzing bomb damage since the enemy first had to raze damaged buildings and clear away debris."[34] This desire to maximize BDA accuracy to determine long-term industrial effects clearly ran counter to the operational commander's desire for quick BDA to determine the effectiveness of sorties and validate tactical procedures.

Procedural and organizational issues also made it difficult to analyze and disseminate intelligence. The *USSBS* recommended that "uniform and standard terminology be adopted and strictly followed by all reporting agencies."[35] The survey authors thought the current procedures were inadequate; they suggested interpreters speculate about the level of interior damage when analyzing photos of targets penetrated by bombs and advised interpreters need bomb load data to help make damage analysis more accurate.[36] Furthermore, multiple organizations working in various levels of command led to duplication of effort and, occasionally, conflicting analyses.[37]

Although the art and science of BDA developed with a solid foundation in World War II, there was ample room for improvement. Following World War II, Maj T. G. Carlson issued a warning for the future: "As the development and evolution of the strategic air concept continues at its present day pace, similar advances in the field of BDA must move forward, also, or the result will be an unbalanced force groping about, as in the dark, seeking the results of expended efforts."[38]

Vietnam

Vietnam offered different assessment challenges. After Korea the intelligence community focused on high-altitude reconnaissance to support nuclear war, while discounting the potential of another conventional conflict.[39] However, with network news organizations reporting nightly the number of pieces of enemy equipment US air attacks destroyed and the number of enemy soldiers they killed, BDA quickly became something the American public followed along with military and political leaders.[40] The targets in Vietnam were elusive.[41] It was difficult for analysts to assess damage to light infantry moving under a triple-canopy jungle or hidden in underground bunkers.[42] Consequently, pressures from senior military leaders for body and truck counts often led to estimates based on speculation.[43] Furthermore, intelligence officers complained that a lack of follow-up investigations on the ground hindered their damage assessments.[44] As one officer so eloquently stated, "Bodies don't cause secondary explosions."[45]

Once again, the BDA community developed procedures to meet the differing requirements of organizations operating across different levels of war. "Forward Air Controller reports, photography, strike crew reports, and sensor data" were the primary sources for damage assessment.[46] SR-71s and other national reconnaissance platforms provided long-range targeting information, but the time required to process and transmit intelligence information from national intelligence agencies was too lengthy for day-to-day operations.[47] To overcome the delays built into processing reconnaissance data back in the United States would have required analysts to be able to acquire and process data from national assets in-theater.[48] Instead, they used tactical air (TACAIR) reconnaissance to provide information for post-strike analysis and restrike decisions.[49] RF-101s, RF-4s, and Q-34 drones provided photographic coverage.[50] Aircraft and drones each had their own strengths and weaknesses. The drones flew lower than manned aircraft and collected valuable information during marginal weather conditions or in highly contested areas.[51] On the other hand, the RF-4s were more flexible, capable of changing routes and targets in flight, while the drones followed routes programmed before launch.[52]

To maximize safety, reconnaissance aircraft often flew to the target area close to the strike package to take advantage of the electronic countermeasure and fighter support.[53] The photo mission timing was a compromise between providing protection and waiting for smoke from explosions to clear the target.[54] Accordingly, the reconnaissance aircraft followed the strike aircraft by five to seven minutes over the target.[55] In addition to accompanying strike packages, quick-reaction reconnaissance aircraft were at the target officer's disposal to photograph the results of attacks made against targets of opportunity.[56] However, the process that planners used to get information from TACAIR reconnaissance was not always timely. Typically, about 12 hours elapsed from the time a reconnaissance aircraft photographed a surface-to-air missile (SAM) site to the time an interpreter checked the film, assessed the damage, and disseminated a report.[57] This was problematic because the enemy could relocate a SAM site in four hours.[58]

Intelligence analysts used gun camera film in a haphazard manner during World War II and Korea, but Tactical Air Command planned to use gun camera footage shot over Vietnam to "provide a permanent record of weapons delivery effectiveness . . . [and] discrepancies noted during assessment [would] assist in developing more proficient aircrews and more reliable weapons delivery systems."[59] During 1967 fighters began to carry strike cameras to photograph attack results.[60] These cameras shot to the rear as the strike aircraft pulled off from the target to photograph the bombs impacting the target area.[61] Although the resolution of these photographs was not as fine as those from reconnaissance aircraft, they provided key information within a few hours of landing to make restrike decisions without waiting for the results of reconnaissance missions.[62] This information was invaluable in Vietnam because Washington periodically withdrew approval for certain target sets if they were not destroyed within a limited period.[63]

Although BDA matured during Vietnam, some dilemmas proved difficult to overcome. Due to the dispersed organization, courier requirements and transmission delays continued to hinder analysis at Seventh Air Force and field organizations.[64] When discussing the duplication of effort between the Seventh Air Force and Military Assistance Command, Vietnam, the Seventh Air Force director of Operational Intelligence noted, "To say that a lesson had or would be learned would be naïve. Commanders traditionally have had their own intelligence staff and have not been prone to accept the estimates and analysis of other organizations."[65] He thought unwillingness to subordinate service, agency, and command prerogatives hindered intelligence assessment and exploitation.[66] High-level interest in each attack required analysts to send poststrike photos to Washington on scheduled courier flights before interpretation was complete.[67] Consequently, agencies differed in opinion over strike results that had to be resolved before Washington released the next set of targets.[68] Additionally, the sheer number of photos requiring interpretation far exceeded the capability of the intelligence agencies in-theater, and stacks of useful photos pilled up unavailable to aircrews.[69] The Seventh Air Force's deputy chief of staff for Intelligence no doubt had all these problems in mind when he disclosed in his 1972 end-of-tour report, "All intelligence sources, analytical formulas and analysis judgments have been applied to the BDA problem, but it still remains an enigma."[70] Clearly, discrepancies remained with BDA tactics, procedures, and organization.

Persian Gulf War

Approximately two decades later, the Gulf War of 1991 strained the BDA process yet again. Analysts applied the same techniques of past wars, but state-of-the-art reconnaissance systems provided the imagery.[71] Once again two different BDA methodologies emerged to meet two fundamentally distinct purposes. At the strategic and operational level, BDA focused on determining the cumulative effect of bombing over time rather than the success of individual missions.[72] However, the joint planning system required timely BDA to operate efficiently and effectively.[73] Campaign planners and aircrews used BDA to confirm that specific targets were destroyed and to verify tactics employed against various types of targets.[74]

As in previous wars, imagery interpretation proved to be an esoteric art rather than a science.[75] The advent of stealth and precision-guided munitions (PGM) allowed attacks against many targets across a theater simultaneously that vastly increased the scope and scale of BDA requirements.[76] It was difficult to analyze the damage caused by precision weapons that left only small holes in targets when most of the explosion's effects were contained within the target.[77] Consequently, an ad hoc BDA process was developed to use physical evidence and military judgment in analysis to meet this requirement.[78]

National assets provided "intercepts of Iraqi communications and signals, as well as imagery" in the "visible, infrared, and radar portions of the electromagnetic spectrum."[79] However, there was not an overarching architecture for using national intelligence information for conducting BDA.[80] Unfortunately, the field often waited several days to get BDA from the national-level imagery production center.[81] In other instances, access to information from national-level systems stopped at the general-officer level.[82]

Making matters worse, the theater commander's tactical reconnaissance assets atrophied since Vietnam. The theater commander directly controlled only a limited number of RF-4s and F-14s with reconnaissance pods, and he had to get permission from Washington to direct the U-2s.[83] Unmanned aerial vehicles (UAV) provided real-time, short-range intelligence for ground and sea operations but were scarce and in high demand.[84] Therefore, theater intelligence staffs developed a BDA methodology in which they interpreted information from "national systems, mission reports, deserter reports, and gun camera film [using] subjective analysis and sound military judgment."[85]

Pilots issued unencrypted in-flight reports to relay the success or failure of the mission.[86] Planners also used videotapes from F-117, F-111F, and F-15E bombing missions that were available as quick as four hours after landing and much earlier than other imagery was available.[87] Unfortunately, A-10s and F-16s recorded what the pilots viewed in their head-up display and, therefore, recorded weapons release but generally not weapons impact.[88] Video recordings were helpful because they confirmed where bombs detonated but did not permit precise damage assessment because of the explosion's blooming ball of fire that obstructed view of the actual damage.[89] Analysts in Riyadh frequently had videotape, gun camera, and radar film delivered by courier for initial indications of bombing accuracy.[90] This served to allay fears of civilian casualties by revealing that the correct targets in Baghdad were bombed.[91]

Unlike World War II and Vietnam, the BDA process did not have time to mature due to the short length of the war. Therefore, many BDA issues remained unsolved. Competing analysis from various organizations caused confusion and dismay. Estimates from national agencies relied solely on national assets and conflicted with those in the field.[92] In some instances, "national intelligence organizations appeared unfamiliar with or unresponsive to the intelligence needs of the wartime commander."[93] Additionally, a lack of common BDA doctrine and procedures created further uncertainty.[94] In one instance, lack of adequate BDA for six days of a suspected underground nuclear facility prevented a reattack recommendation before the war ended.[95]

Establishing the theater intelligence center and processes ad hoc with officers from outside organizations entering an organization without an established intelligence architecture hindered the processing and dissemination of damage assessments.[96] The intelligence system as a whole was unprepared for the sheer size and pace of the BDA processing and dissemination task.[97] Effects-based targeting troubled analysts as Gen H. Norman Schwarzkopf facetiously teased his intelligence officer for claiming a bridge was 50 percent destroyed when two of four spans were destroyed, fully preventing use of the bridge.[98] As in past wars, imagery was the intelligence product of choice for combat commanders at all levels.[99] Although the terrain was suitable to optical imagery, weather often obscured the target from poststrike analysis.[100] Incompatibility of imagery distribution systems obstructed analysis and dissemination; only four of 12 secondary imagery dissemination systems in-theater could pass information to other systems.[101]

Furthermore, BDA training doctrine and standards did not exist and resulted in "too few and not adequately trained analysts" available for the war.[102] Lack of information on weapons applied, desired aim points, and desired damage levels limited analysts' efforts.[103] Intelligence staffs were not prepared for the enormity of the task; some lacked adequate training and the long-standing practice of "simulating the production of bomb damage to simplify and shorten" exercises left the analysts with little actual experience.[104] New precision weapons allowed Airmen to employ ordnance in ways that made it difficult to determine how much damage they were actually causing.[105]

The ability to rapidly change targets during planning hindered the damage assessment process because intelligence-collection managers could not synchronize intelligence collects with strike missions.[106] Couriers had to fly film from the U-2 and RF-4 missions to Riyadh for exploitation.[107] To illustrate the magnitude of the collection task during Operation Desert Storm, the system processed 1.3 million ft of U-2 imagery, and analysts selected more than 53,000 images for printing.[108]

Yet, key intelligence staffs failed to pass information down to the air wings and ground units.[109] Flight crew members received little BDA in units not equipped with in-flight recording devices or organic reconnaissance assets.[110] Part of the problem was that communications down to the tactical level were inadequate to relay the necessary intelligence.[111] Flying units resorted to sharing information on secure telephones to gather the necessary information on previous strike results to plan future strikes.[112]

Postwar analysis of the Gulf War BDA process led *Gulf War Air Power Survey (GWAPS)* authors to report, "Few assertions about the Gulf War could command as much agreement as the inadequacy of BDA, but there was found no such agreement about the causes of that inadequacy."[113] *GWAPS* also noted, "The revolutionary changes in the way American forces conducted combat operations during Operation Desert Storm outstripped the abilities of the BDA system."[114] Imperfect BDA led to unnecessary restrikes "placing crews and equipment unnecessarily at risk."[115] Commanders agreed that "the supply of the right kinds of BDA simply could not keep up with the demand."[116] Equally telling, Representatives Les Aspin (D-Wis.) and William L. Dickinson (R-Ala.) reported the air campaign "could have been more effective had there been a greater ability to process and disseminate target and other information, especially in the assessment of damage done by allied air strikes."[117] As *GWAPS* participants concluded, "The existential problem of bomb damage assessment means that the fog of war will persist."[118]

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Chapter 3

Battle Damage Assessment Today

I am tempted to declare that whatever doctrine the Armed Forces are working on, they have got it wrong. I am also tempted to declare that it does not matter that they have got it wrong. What does matter is their capacity to get it right quickly when the moment arrives. It is the task of military science in an age of peace to prevent the doctrine being too badly wrong.

—Sir Michael Howard

Following the Persian Gulf War, the joint intelligence community endeavored to address the difficulties identified in the war's aftermath. The Military Targets Intelligence Committee (MTIC) created the BDA Working Group (BDAWG) with representatives from the unified commands, services, Joint Staff J-2 (Directorate of Intelligence), Defense Intelligence Agency (DIA), and national agencies to foster the development of joint BDA doctrine and procedures.[1] Subsequently, the BDAWG attempted to standardize terminology, establish requirements for a shared BDA database, evaluate required support architecture for BDA, assess BDA training needs, and assist unified commands in developing BDA plans.[2] In addition, the Joint Staff created a new office, the BDA Branch, Deputy Directorate of Intelligence for Targets (J-2T-1B), as the focal point for BDA issues.[3]

Doctrine

DIA and the BDAWG successfully addressed several shortcomings following the Persian Gulf War, but comprehensive BDA doctrine remains elusive. DIA set out to build a common knowledge base among BDA users by producing two reference documents: *BDA Quick Guide* and *BDA Reference Handbook*. The BDAWG broadened the BDA concept from *bomb* to *battle* damage assessment and developed associated BDA terminology to incorporate in joint publications (see glossary).[4] Additionally, they standardized BDA reporting formats.[5] Meanwhile, the Joint Staff published Joint Publication (JP) 2-01, *Joint Intelligence Support to Military Operations* and JP 3-60, *Joint Doctrine for Targeting* to fill the doctrinal void. However, at the time of this writing (Spring 2002), BDA doctrine remained unsettled as JP 2-01.1, *Joint Tactics, Techniques, and Procedures for Intelligence Support to Targeting* has not been signed three years after being released for final coordination on 29 February 1999.

Nonetheless, the JP 2-01.1 draft accurately described the three phases of BDA currently conducted during combat operations (table 1).[6] Analysts developed an initial BDA judgment (basically a hit-or-miss determination) from a single source, usually visual, to provide timely feedback for the planning cycle.[7] Sometime later, analysts conducted supplemental analysis and compared information from multiple intelligence sources to amplify the initial BDA estimate, determined the functional damage to the target, and determined an initial assessment of effects on the target system.[8] Analysts and subject matter experts assessed the target system and evaluated supplemental BDA to determine how well operational objectives were achieved.[9]

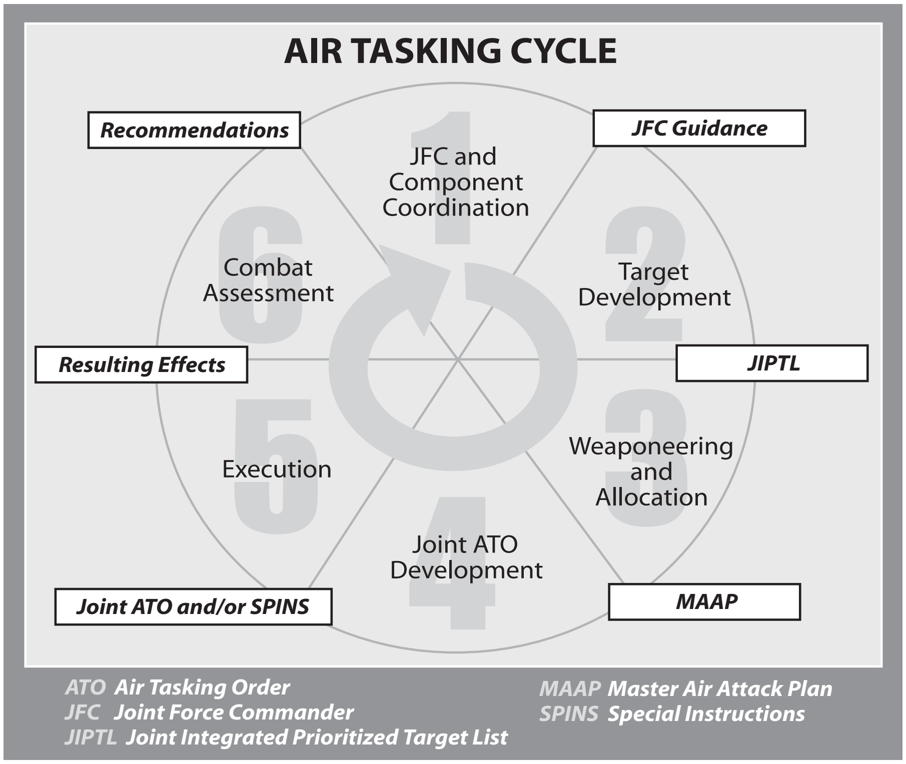
Table 1

Battle Damage Assessment Phases

BDA Phase	*Results*	*Data Sources*
Phase One Initial	–Initial Report (Hit or Miss) –Initial Physical Damage Assessment	–Aircrew Debriefs –Forward Observer –Weapon System (Aircraft Cockpit Video) –Theater and National Sources –Open Source Intelligence
Phase Two Supplemental	–Physical Damage Assessment –Functional Damage Assessment –Initial Target System Assessment –Munitions Effects	–All Sources
Phase Three Target System Assessment	–In-depth Target System Assessment	–All Sources with Subject Matter Expert Input

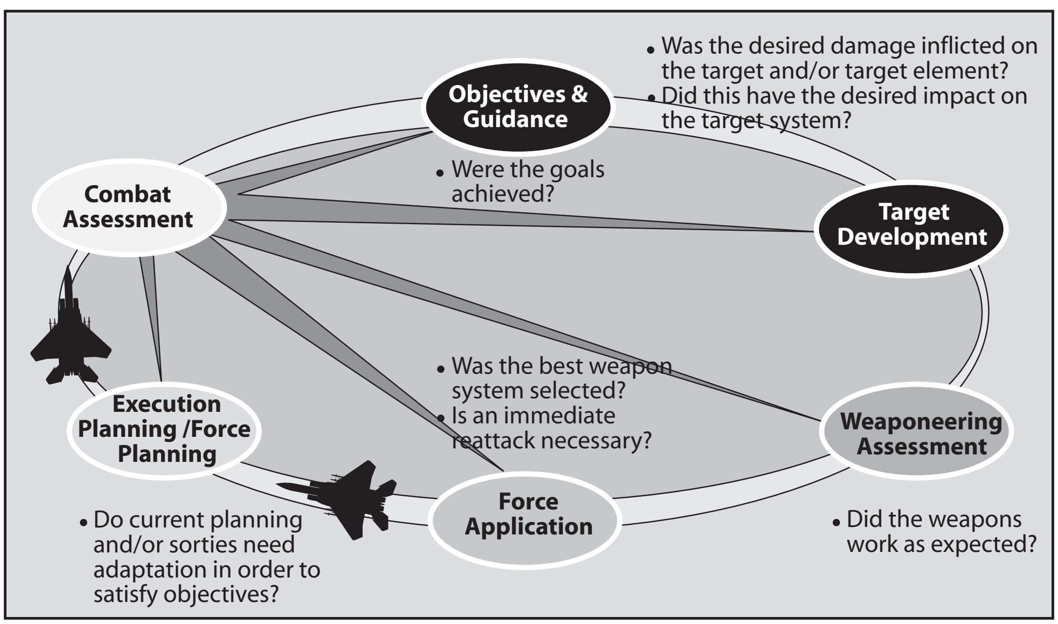
Adapted from Joint Publication (JP) 2-01.1, *Joint Tactics, Techniques, and Procedures for Intelligence Support to Targeting,* final coordination, 29 January 1999.

Furthermore, JP 2-01.1 revealed that the intelligence agencies better understand how important BDA is to combat assessment and the air targeting cycle (fig. 1). Joint targeting doctrine portrayed the basic air targeting cycle as a linear process. This targeting concept portrayed combat assessment merely as feedback at the end of a process.[10] But JP 2-01.1 more accurately depicted the dynamic influence that BDA information had on all phases of the targeting cycle (fig. 2).[11] Rather than just one discrete targeting cycle occurring at any given time, multiple targeting cycles operated in different phases simultaneously. While planners are working on target development for a period more than three days in the future, others are allocating aircraft and weapons for 48 to 72 hours out. At the same time, other planners are finalizing the next day's air tasking order (ATO), while other personnel monitor the execution of the current ATO. Meanwhile, analysts are scrutinizing the results of multiple days' strikes. In addition to providing feedback for commanders, the analysts' findings concurrently affect the planning and execution across the four groups who are working on four distinct phases of the air tasking cycle. Thus, BDA directly influences varied segments of several target cycles simultaneously. Instead of a single circle, the targeting process more resembles a spiral with the effects of BDA reaching across and along the spiral.



Source: Adapted from JP 3-60, *Joint Doctrine for Targeting,* 17 January 2002.

Figure 1. Joint Air Tasking Cycle



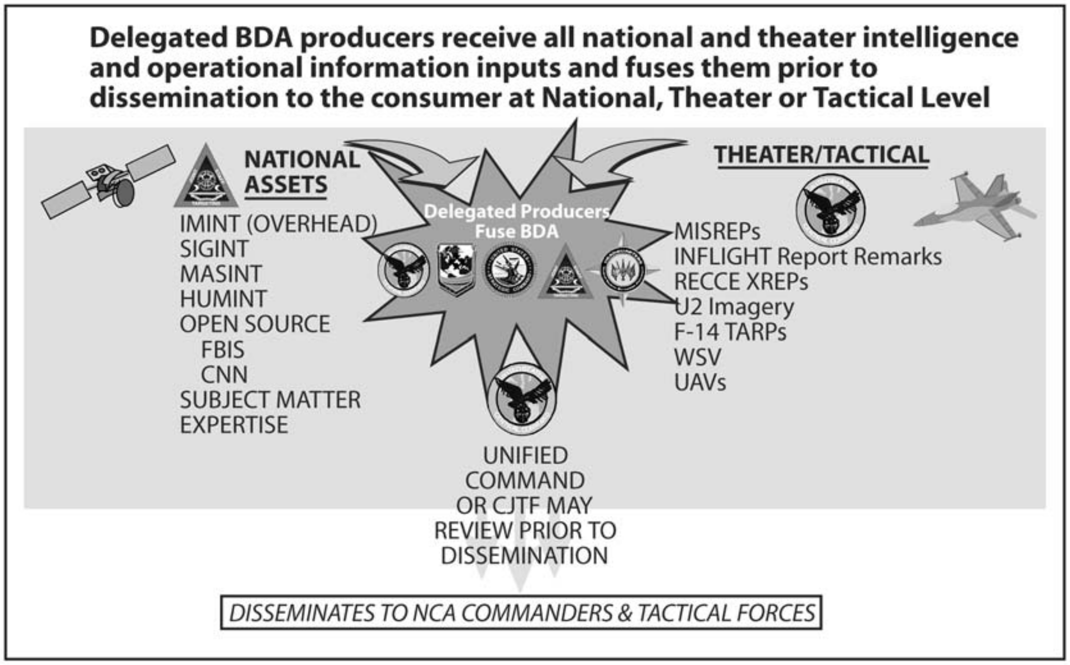
Source: Adapted from JP 2-01.1, *Joint Tactics, Techniques, and Procedures for Intelligence Support to Targeting,* final coordination, 29 January 1999.

Figure 2. Combat Assessment Cycle

In addition to the developments within joint doctrine, the Air Force addressed BDA issues in current Air Force doctrine. Air Force doctrine authors emphasized the importance of ensuring BDA keeps pace with improvements in weapons technology.[12] The authors espoused, "Being able to destroy targets is only half of the equation; unless that destruction is confirmed through BDA the question of reattack requirements will remain open."[13] Moreover, Air Force doctrine identified the importance of establishing procedures for modifying current flight operations due to BDA.[14] The writers of the 16 April 2001 Air Force Doctrine Center Handbook (AFDCH) 10-01, *Aerospace Commander's Handbook for the Joint Force Air Component Commander (JFACC),* stressed the importance of revalidating current targets based on incoming or up-to-the-minute BDA.[15] AFDCH 10-01 was revised and retitled 16 January 2003 to *Air and Space Commander's Handbook for the JFACC.* Furthermore, pertinent Air Force instructions and pamphlets described the dynamic nature of BDA and its use for weaponeering, target study, restrike decisions, target system analysis, and reconstitution estimates.[16] While not all-encompassing, these doctrine improvements are significant.

Procedures

To implement this doctrine, the J2-T developed and the MTIC approved guidelines assigning BDA responsibilities during joint operations.[17] Due to the inadequate size of intelligence staffs in the unified commands, any large operation quickly outstrips the staff's ability to perform BDA analysis.[18] To help resolve this problem, the J2-T guidelines require the national intelligence staff and those of other commands provide BDA support to the overloaded command in a concept called Federated BDA (fig. 3).[19] Intelligence centers at unified commands other than those responsible for the prosecution of a conflict receive BDA information and conduct analysis on specific target sets. Intelligence centers then send this BDA to the responsible theater intelligence center for review and dissemination. While all unified commands are eligible for tasking under the Federated BDA process, the "supported CINC is the final authority for all BDA in a particular operation."[20] This arrangement should prevent the recurrence of problems encountered in the Persian Gulf War when various national agencies frustrated General Schwarzkopf by competing with theater analysts with contradictory assessments. To implement this solution, the J2-T assists commands in establishing concepts of operations, partner responsibilities, and architecture requirements.[21] The National Military Joint Intelligence Center (NMJIC) facilitates the coordination and dissemination of information among partners in the process.[22] Finally, the J2-T has already encouraged commands to test the Federated BDA process by practicing their procedures during command exercises.[23]



Source: Adapted from Dana Frazier and Scott Repeta, "Better BDA for the Warfighter," Joint Battle Damage Assessment Joint Test and Evaluation, n.p., on-line, Internet, 28 February 2002, available from http://www.jbda.jte.osd.mil/publications/jbdaalsa.doc.

CJTF, combined joint task force
CNN, Cable News Network
FBIS, Foreign Broadcast Information Service
HUMINT, human intelligence
IMINT, imagery intelligence
MASINT, measurement and signature intelligence
MISREPs, mission reports
NCA, National Command Authorities
RECCE XREPs, reconnaissance auxiliary reports
TARPs, target acquisition and reconnaissance platoon
WSV, weapon system video

Figure 3. Structure of Federated Bomb Damage Assessment

The draft JP 2-01.1 described the responsibilities and functions already exercised within the BDA process. The NMJIC served as the sole point of contact for BDA support from assets tasked at the national level.[24] Consequently, the NMJIC integrated the efforts of the National Security Agency (NSA), National Imagery and Mapping Agency (NIMA), Central Intelligence Agency (CIA), and Joint Staff to ensure a unified process.[25] The NMJIC operated a BDA cell that provided voice reports and initial imagery to theater commands during phase one of the BDA process.[26] Meanwhile, the theater intelligence center developed initial BDA estimates from unit reports, cockpit video, and theater reconnaissance assets.[27] Hours or days later, the NMJIC transmitted a supplemental report to the command after all national-level sources were analyzed in the phase-two assessment.[28]

In the interim, the theater BDA cell developed a supplemental BDA analysis based on other supporting commands' assessments using the federated process and internally developed information.[29] Finally, NMJIC and the command BDA cells may conduct extensive assessment of relevant target systems (phase three) depending on the nature of the conflict, tempo of operations, and necessity.[30] Thus, the current process generally complies with contemporary doctrine using Federated BDA procedures.

Prior to the Persian Gulf War, the NMJIC developed a tracking system for targets of interest for intelligence purposes at the national level. This system labeled each target with an individual Basic Encyclopedia (BE) number for tracking.[31] The NMJIC built databases for countries with significant targets identified with a BE number. Unlike the Gulf War, all analysts now use the BE number to track a specific target for reconnaissance, strike, and BDA to coordinate BDA processing among the intelligence centers.[32] This procedure successfully eliminated most of the confusion over fixed targets that occurred during the Gulf War, but analysts still struggle to manage mobile targets.

Training

The services and the Joint Staff have attempted to overcome the training deficiencies identified during and following the Persian Gulf War. Unified commands now exercise their BDA procedures during BDA-only exercises and to a limited extent during major joint exercises.[33] The BDA-only exercises serve to train intelligence personnel on BDA processes and sharpen their imagery interpretation skills.[34] However, during Air Force exercises, intelligence staffs still simulate much of the BDA process and associated analyses.[35]

In addition to training during exercises, intelligence officers receive various levels of instruction on BDA analysis from both joint and service intelligence schools. The Joint Warfighter Center's Joint Targeting School offers a one-week course dedicated to educating operations and intelligence personnel on the BDA process.[36] This course provides a "detailed background in damage assessment and the flow of information during the three phases of BDA."[37] The Air Force has also begun to emphasize BDA during initial training for intelligence personnel and has established several BDA-related specialty courses for its personnel and those of other services.[38] These efforts include computer-based training courses for intermediate analysis training with one 40-hour course focusing on damage assessment.[39] Targeteers may now undergo a special technical Combat Targeting Course lasting seven weeks that covers the targeting cycle including BDA.[40] Finally, the Air Force created a seven-day Mobile Conventional Weaponeering Course with instructors traveling to various bases to teach personnel at their home locations.[41] However, training improvements trail the developments made in other areas of the BDA process.[42]

Technology

The Joint Staff and services have solved a number of the major technological issues identified during Operation Desert Storm. The intelligence community developed a system to disseminate imagery from national-level organizations to the theater intelligence centers. Now, theater BDA cells can download raw or phase one processed imagery from a national imagery server maintained by NMJIC.[43] This capability makes it unnecessary to send hard-copy photos, which noticeably reduces the time required to receive national-level imagery products. However, this process may tax the communications system and has overloaded the system even during BDA-only exercises.[44]

The Marines placed renewed emphasis on tactical reconnaissance following the Gulf War. They fielded the Advanced Tactical Airborne Reconnaissance System (ATARS) pod on the F-18D.[45] ATARS can take pictures in flight then downlink the reconnaissance data to a mobile Marine site for exploitation.[46] This capability gets the BDA analysis to the Marine tactical and operational commanders quicker.

The Air Force made improvements in the U-2 aircraft and associated ground systems, which significantly enhanced the timeliness of data transmission. The U-2 now transmits information to ground stations in the United States or within line of sight (LOS) in the theater.[47] Furthermore, the imagery and analysis from these ground stations are compatible with the current imagery dissemination systems.[48] Therefore, intelligence analysts located in common ground-processing stations in the United States receive reconnaissance data relayed by satellite directly from the U-2 or LOS ground stations in the time it takes to transmit the data.

Finally, a variety of organizations worked together to improve the distribution of cockpit video. The air operations center (AOC) receives digitally transmitted cockpit video to include in the BDA process.[49] Combat camera personnel then prepare the video for digital transmission from the AOC.[50] This process enables rapid delivery of cockpit video to intelligence centers for BDA analysis. As a side benefit, commanders receive higher quality video much quicker for use in press conferences.

Unresolved and Emerging Issues

Although those responsible for the BDA process made numerous improvements, significant hurdles remain unsolved and new issues developed. The new process incorporates the national-level expertise in imagery exploitation and dissemination, but BDA imagery and analysis from the NMJIC to the AOC continues to be delayed due to manual-processing limitations, procedural impediments, and satellite-tasking constraints.[51] While NIMA's imagery experts are exceptional, their participation in the BDA process comes at the expense of NIMA's main mission.[52] As a result, differences in organizational priorities and agendas make the BDA process less responsive than it should be. Time delays range from five to 12 hours for single, high-priority analyses and up to 48 hours for more typical analyses.[53] To minimize these delays for high-priority strikes, planners must synchronize strike times with satellite coverage to minimize the wait for poststrike satellite imagery.

When conducting analysis, electro-optical (EO) imagery remains the accepted norm, and this is a problem because inclement weather conditions frequently obscure the target from EO collection. New predicaments arose following the Persian Gulf War. Operators can now strike targets with Global Positioning System (GPS)-guided munitions in weather conditions that make assessing the status of the target impossible.[54] Intelligence officers in the AOCs recognize the limitation of EO but assert that theater-level decision makers' analysts will only accept EO imagery from national reconnaissance systems to determine BDA.[55]

The current BDA process supporting Operation Enduring Freedom in Afghanistan does not effectively disseminate BDA to operational units and their aviators.[56] Instead, the flying units fall back on visual observation relayed in mission reports and cockpit video for mission feedback as in prior conflicts.[57] As aircrews can now accurately strike targets without observing their weapons' impact, that sole source of information is unavailable to aircrews during many attacks. Consequently, as aircrews now rely predominately on GPS-guided munitions, they are left with less feedback on their weapons delivery tactics than in prior conflicts.

UAVs are another source of BDA information. For example, the Predator UAV delivers real-time video imagery broadcast direct or via satellite to many locations. Operators and analysts can directly observe a target for acquisition, tracking, BDA, and even attack. However, one drawback to the Predator is video granularity. The current picture quality is not sufficient for second—or third—phase BDA analysis.[58] Therefore, the Predator provides initial BDA information only.

One example of the BDA process used in Operation Enduring Freedom illustrates current BDA difficulties. Gen Tommy Franks and his staff instructed the JFACC to destroy the aircraft in Afghanistan even after coalition aircraft rendered the runways unusable.[59] Consequently, coalition aircraft struck every aircraft.[60] In reviewing the poststrike BDA, the JFACC and his staff determined the enemy aircraft were damaged beyond repair, so they reported all 25 of the aircraft as destroyed up the chain of command to Central Command (CENTCOM).[61] However, General Franks later contacted the JFACC to determine why only two of the 25 aircraft were actually destroyed.[62] In sorting out the discrepancy, air planners discovered that the CENTCOM BDA cell would not consider an aircraft destroyed unless an EO image revealed catastrophic damage to the aircraft.[63] At the time of the inconsistency, the CENTCOM staff possessed limited poststrike imagery of the aircraft. Ultimately, it took the CENTCOM staff at least two more days to assess all the aircraft as destroyed.[64] This was of particular interest because General Franks briefed aircraft status up his chain of command.[65] Thus, even in a limited conflict in which only 25 aircraft were struck, the formal BDA system could not adequately evaluate the effectiveness of airpower in time to affect operations in less than two days.

To the credit of all those involved, the BDA process vastly improved during the 1990s. The intelligence community made advances by codifying doctrine, establishing procedures, improving training, participating in exercises, and integrating technology. However, old issues remained unsolved while new difficulties arose as the planning and execution process became increasingly more dynamic. To help resolve these problems, the Joint Test and Evaluation Office established a joint BDA program to tackle the issue of BDA support.[66] The following problem statement describes the scope of this effort: "Study of the joint targeting process in support of the Joint Force Commander indicates that, while enhancements have been implemented, battle damage assessment still needs improvement to provide effective and timely assessments of fixed and mobile targets."[67] Official statements such as the one above suggest that gathering, analyzing, and disseminating accurate, timely BDA to all relevant decision makers remains a hurdle.

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25. JP 2-01.1, C-14.
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28. JP 2-01.1, C-15.
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41. Mobile Conventional Weaponeering Course, 315th Training Squadron, Goodfellow AFB, Tex., n.p., on-line, Internet, 28 February 2002, available from http://www.good fellow.af.mil/~trs315/MTTPage.htm.
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Chapter 4

Potential Solutions

In the development of air power, one has to look ahead and not backward and figure out what is going to happen, not too much what has happened.

—William "Billy" Mitchell

Air power is the most difficult of military force to measure or even to express in precise terms. The problem is compounded by the fact that aviation tends to attract adventurous souls, physically adept, mentally alert and pragmatically rather than philosophically inclined.

—Winston Churchill

Although several impediments exist, many potential solutions offer the promise of improving BDA timeliness. This study examines a wide range of technological, procedural, and organizational approaches for getting BDA to users quicker without sacrificing accuracy. Proponents of technological solutions are eager to show how their research or product can solve specific problems with existing BDA systems. People working within those systems are quick to point out that procedural or organizational changes can also make BDA more responsive to user needs. While each kind of solution offers its own distinct advantages, each is also limited in ways that might constrain its utility. This chapter describes basic conceptual remedies and discusses the experiments and studies various agencies are conducting to test these concepts. This chapter also evaluates the advantages and limitations of the proposed solutions in terms of how much they improve BDA support to users who plan and execute air operations.

Technological Solutions

Airmen have turned to technology to solve innumerable challenges in the past, and analyzing the effects of airpower is no exception. Technical innovations offer numerous prospective avenues to make BDA timelier. This section explains possible solutions using satellite, UAV, aircraft, munition, and unattended sensors. Each pursues a distinctive method of positioning a sensor for data collection. However, all solutions have limitations of how each method employs sensors.

Satellite Sensors

Improvements in satellite technology may make information available to users quicker by exploiting the unique vantage of space. The concept of real-time imagery from space is attractive since satellites are able to pass freely over hostile terrain. With improvements in processing speed of satellite systems and ground equipment, analysts could receive satellite imagery directly in the theater or AOCs, rather than rebroadcast through a secondary relay from national-level intelligence agencies. Given high enough collection priority, space operators can direct satellites to observe planned targets before, during, and after an attack. Moreover, the satellite data-processing system could automatically download and correlate imagery directly into a database for analysis. With this arrangement, analysts could overcome some of the processing delays caused by differing organizational priorities and time-consuming manual processing.[1]

US capability to gather information from satellites is remarkable. Satellites offer unfettered access to regions that air-breathing assets cannot reach because of political constraints. Satellites can gather data from far-flung reaches of the globe without requiring nearby basing rights or lengthy deployment and flight times to the area of interest. The systems that gather and process satellite data are well established and reliable. Satellite sensors can gather high-definition data from EO/infrared (IR) imagery for surface observation and from synthetic aperture radar (SAR) imagery for peering through clouds or at night. Thus, US satellite sensors are capable of high-fidelity collection nearly anywhere in the world.

However, relying more heavily on data collected from satellites would not solve all of our BDA problems. Decision makers are so enamored with EO imagery that they often refuse to accept BDA not based on that source.[2] The United States and its allies conduct many air strikes during the night when EO imagery is not viable. The infrastructure needed to launch and maintain satellite systems is so extensive and costly that, for the near future, national-level organizations will most likely continue to manage those systems, rather than cells at the theater or component level. Since they are national assets, Airmen will continue to compete for satellite coverage with other services and national agencies. Furthermore, Airmen will have to wait for national-level system personnel to process data according to priorities established outside the theater. Although machines might initially process the imagery, analysts must interpret the data, which causes a delay before they disseminate products to the field. Even when operational planners have high-priority needs, they must provide organizations responsible for satellite tasking with enough lead time to task the satellite sensors without disrupting other collection priorities. Moreover, to enable near-real-time imagery for BDA, Airmen would have to adapt strike times to correspond with satellite coverage. Regrettably, satellites may only pass over a target twice per day during times optimal for EO sensors. This presents a two-faceted problem: on one hand, our adversary may know these satellite pass times; on the other hand, planners may not find these specific times optimal or feasible. As strike times and locations often change, the air operations planning process demands a degree of flexibility that national satellite systems frequently cannot support due to tasking lead times. Consequently, while satellites can provide the sensor fidelity necessary for BDA, they may not be responsive enough to the dynamic changes that occur during the planning and execution of air operations.

Unmanned Aerial Vehicle Sensors

The intelligence collection from UAVs is an evolving capability and offers opportunities to supply real-time BDA. Proponents cite the UAVs record of providing 24-hour, real-time surveillance in Afghanistan to claim UAVs are capable of supporting BDA collection requirements in future conflicts.[3] Medium-level UAVs, such as the Predator, typically operate at 15,000 ft with a mission duration of approximately 24 hours and provide real-time, streaming video from an EO/IR camera.[4] The Predator currently broadcasts this information to many locations including the theater commander, the theater intelligence centers, and the AOC.[5] The potential also exists to broadcast video or still photos to the cockpit. High-level UAVs, such as the Global Hawk, fly around 65,000 ft and remain airborne for 35 hours or more.[6] High UAVs could loiter for extended periods and transmit still photo EO/IR imagery and SAR data to the theater intelligence center, AOC, or directly to the cockpit in real time.[7] The United States could treat high UAVs such as low-orbiting, theater-directed satellites, as Gen John Jumper, Air Force chief of staff, said, "to provide persistence over the battlefield."[8] Analysts could correlate the UAVs' collection with strikes to gather real-time information on the effects of attacks. The Defense Advanced Research Projects Agency (DARPA) also experimented with stealthy UAVs that added a capability which would enable these platforms to gather BDA information in a high-threat environment.[9]

Theater and component commanders may find UAVs more responsive than satellites. The UAVs will most likely transfer to their command during a crisis. As a theater or component asset, the commanders and planners could task and coordinate UAVs to cover desired strikes as these platforms are not subject to the constraints of orbital mechanics. When the attack plan changes or new targets emerge, the UAV is capable of flexing with little notice. Additionally, commanders have discovered that the Predator's streaming video serves their needs better than still photos for some applications. Consequently, the UAV proved its utility to the US military and political leaders during recent operations in Afghanistan.[10] The Pentagon budgeted to purchase 37 additional UAVs that following year, so the number of UAVs available to the JFACC should increase.[11]

However, using today's UAVs to gather BDA information would have certain drawbacks. The quality of the highly touted, moving video from the Predator UAV is frequently inadequate for developing phase one BDA.[12] Furthermore, the video streaming into the AOC from multiple Predators could quickly overload the analytical and processing capacity on the AOC operations floor.[13] Alternatively, the Global Hawk delivers high-quality, still imagery, but the data currently requires processing at a central ground station before analysts can broadcast useful BDA information to the AOC. To gather BDA information in real time for multiple simultaneous attacks, planners would need to dedicate one UAV per geographically separated target, which would result in a swarm of UAVs over the battlefield. As the current UAVs are much slower than the attack aircraft, the UAVs would have to proceed towards the target prior to the attack. If the adversary can detect the inbound UAVs, their presence might reveal an attack is imminent and even disclose the intended target. If the environment is not as permissive as Afghanistan, the adversary may be able to shoot down the UAVs or use the notice to mount an effective defense against the ensuing attack. The immense bandwidth required to monitor, control, and receive intelligence data from UAVs is another severe limiting factor. During operations in Afghanistan, the Air Force was able to keep only one Global Hawk and two Predators airborne simultaneously due to bandwidth limitations.[14] Moreover, bandwidth constraints forced the Global Hawk operators to transmit video of reduced fidelity and turn off other sensors.[15] As the current military bandwidth capacity is insufficient, the military relies on commercial satellites for a significant amount of bandwidth.[16] However, the commercial sector is currently incapable of supporting many UAVs, and the lack of growth in civilian bandwidth capacity means this situation is likely to persist.[17] Additionally, UAV costs are becoming a concern, and the Air Force has asked Northrop Grumman to propose methods for reducing the projected $48 million production cost for each Global Hawk airframe by 25 percent.[18] The UAV systems also rely on a specifically configured, dedicated infrastructure. Each requires ground stations with skilled operators, adequate basing facilities, and support personnel to launch, recover, and maintain the UAVs. Considering all these factors, it appears the UAV is an effective platform for collecting real-time BDA on a few targets but currently is not a method for gathering data in real time on all strikes.

Aircraft Sensors

Equipping each strike aircraft with sensors capable of collecting BDA information is another technical avenue to producing timely BDA. Each aircraft could fly with sensors capable of tracking munitions and their effects with EO/IR imagery. Another option beyond EO/IR is to outfit aircraft with SAR to collect information day or night in all weather conditions. DARPA is working to develop advanced algorithms for SAR processing to determine weapon effects automatically based on geometric changes and the creation or distortion of cavity returns in a target.[19] This SAR approach will be particularly useful when catastrophic physical destruction does not occur. Researchers are also investigating algorithms for existing sensors already onboard current aircraft or planned for future platforms.[20] An alternative sensor method called laser remote sensing provides insight into the composition of the debris cloud or explosive fireball produced when weapons detonate or when secondary explosions occur.

Laser remote sensing uses optical absorption spectroscopy of the light absorbed from a laser directed at the target medium to determine the medium's chemical composition.[21] As a result, this sensing method may hold the promise of identifying the internal composition of a target structure such as a hardened aircraft shelter. Any of the previously mentioned sensors could automatically track munitions from aircraft separation to impact and observe the target area after detonation. Aircrews could program desired collection parameters before flight to reduce cockpit workload, while maintaining the ability to direct these sensors in flight to preserve flexibility. Alternatively, designers could build a sensor system capable of allowing personnel on the ground or in another aircraft to dynamically task the sensors. In this manner, aircraft might provide BDA information on targets previously struck by other aircraft. Any of these configurations would be capable of broadcasting this BDA information automatically or by pilot direction, thus eliminating the delay caused by having to wait for the aircraft to return to base.

Placing sensors on aircraft would offer many advantages. Aircrews might have direct access to the sensor information for restrike decisions. This might reduce the inevitable friction operators experience whenever they have to coordinate two dissimilar platforms. With the sensor on the same vehicle that strikes a target, planners would no longer have to coordinate platforms to gather BDA with the strike. Consequently, air operations could flex when targets or times change. Furthermore, aircraft-based sensors are automatically in the right place at the right time when they need to strike emerging or mobile targets. By placing sensors on proven aircraft, designers could avoid the demands of platform design and focus on sensor design and integration, which potentially reduces cost and time required. By employing sensors onboard aircraft already flying strike missions, the services would avoid increasing basing requirements as well.

However, gathering BDA data from aircraft sensors would also pose disadvantages. Aircrews might employ their aircraft or weapons with tactics and flight profiles that obstruct the sensor's view of the target at the time the weapon impacts. Additionally, current and projected munitions such as the Joint Air-to-Surface Standoff Missile (JASSM) are capable of striking targets from standoff ranges as far as 200 nautical miles.[22] Aircrews will most likely employ these missiles beyond the LOS of the aircraft, so aircraft-based sensors would not be able to monitor the missile's detonation. If the target is within sensor range, manually analyzing sensor information in the cockpit could dramatically increase aircrew workload at a most inopportune time. Comparing prestrike and poststrike information by machine processing might relieve the workload requirements. However, this capability does not currently exist, and some research projects in this area have moved on to pursue methods of detecting movement (a rattle if you will) of targets due to weapon detonation.[23] Although useful, the aircrew would still have to infer from the detection of this rattle whether the weapon affected the target as intended. Therefore, aircraft-based sensors may be an effective method for at least gathering real-time BDA data but only when the aircraft is within LOS of weapons detonation.

Munition Sensors

Munition sensors offer an alternative approach to solving the BDA challenge. Rather than remotely sensing from the delivery aircraft, these sensors gather BDA information from a unique vantage point. Since many current PGMs do not use sensors to find and strike a target, researchers are evaluating adding sensors to munitions for BDA data gathering.[24] An obvious approach is to place a sensor on bombs or missiles and broadcast the sensor information back to the aircraft. Such an arrangement would broadcast information until the weapon detonates, thereby providing data on impact location. Possible sensors in addition to EO, IR, and SAR include telemetry sensors to transmit munition location via GPS coordinates as well as data on the characteristics of the medium the munition passes through before it detonates. Analysts may use this telemetry data to determine what building level the weapon detonated or if the weapon reached a deeply buried target. However, this method does not completely reveal what happened after weapon impact. Trailing the camera behind a bomb may remedy this inadequacy. To test this concept, researchers recently attached a housing with a camera that deployed on a 1,000-foot tether immediately after weapons release.[25] The camera continued to transmit for roughly one second after the bomb's impact that reveals the initial munition blast pattern before the camera itself impacted.[26] If used operationally, the blast pattern will help to confirm the weapon exploded as intended (i.e., detonated with a high-order explosion). However, the debris cloud will almost certainly obscure the target from the time the weapon detonates until after the camera impacts. Another concept under review is to attach a sensor to a munition that will detach and follow at a retarded rate of descent due to an inflatable drag device on the camera housing.[27] This design should supply approximately 10 seconds of video after weapon impact.[28] The transmission duration is long enough to transmit imagery of secondary explosions. However, the transmission length is still insufficient for the debris cloud to clear the target. To extend the transmission time from munition sensors, engineers could attach a deployable glider to a bomb that would detach and provide approximately 30 seconds of video.[29] If the wind is blowing favorably, the debris cloud might clear enough to allow the glider's sensor to gather information on the status of the target after weapon impact. All of these sensor configurations are capable of broadcasting information directly back to the aircraft or another entity.

Employing munition sensors offers a few distinct benefits. Every weapon—depending on sensor configuration—could potentially collect data to validate target impact and high-order detonation. Gathering BDA information from the munitions themselves would free planners of collection-coordination requirements for initial BDA thereby reducing friction and preserving flexibility during execution. This sensor configuration may provide feedback on targets destroyed at long ranges or otherwise obscured from the aircraft without placing another platform at risk. Moreover, some designers, operators, and analysts are already comfortable with some munition-based sensor configurations since the military previously used these sensor configurations for weapon guidance.

However, gathering BDA information from munition sensors would have limitations. If the sensor remains with the weapon, it only identifies where the weapon impacted as opposed to what happened. Tethered sensors may confirm high-order detonation, but their transmission time would most likely be too limited to determine damage inflicted. Additionally, the optimal configuration for deploying the tether from the tail of the munition is incompatible with the current GPS guidance tail kits on weapons such as the Joint Direct Attack Munition (JDAM), the current weapon du jour.[30] A munition-released glider would have a longer transmission time, but even that would likely be inadequate to ensure debris clouds from a kinetic weapon are dissipated enough to determine the target's poststrike condition. As the sensors are destroyed in all munitions-based configurations, designers would need to keep sensor costs down to ensure they are inexpensive enough for the services to be able to purchase an adequate supply for inclusion on most strikes. Additionally, designers would need to develop a system to gather and relay data bursts from a munition sensor beyond the LOS of the attacking aircraft. The services are currently striving to develop a system in time to gather the information from the new JASSM.[31] Thus, munition sensors seem to be a workable choice for attacks beyond LOS, but developers must design sensor configurations to gather, broadcast, and relay enough data to support BDA requirements.

Unattended Sensors

A final technological solution involves the use of unattended sensors. Similar to a glider that detaches from a munition, aircraft could directly deploy low-cost, disposable gliders. The Air Force's Information Warfare Battlelab conducted tests to demonstrate the concept that employs a vehicle they named a Microglider.[32] The Microglider measured 22 inches long, weighed under 12 pounds, navigated autonomously using GPS, and flew at 100 knots with a duration of one minute per 1,000 ft of altitude.[33] These gliders could broadcast BDA imagery for 30 minutes, while revealing the effects of an attack and how the adversary behaves afterward. DARPA is developing another concept designated as the Micro Air Vehicle (MAV).[34] The agency intends to develop aircraft no larger than 6 inches in any dimension, capable of maneuvering with 6 degrees of freedom to observe an area or deploy sensors.[35] The MAV could deploy to an urban environment and perch upon a building like a high-tech gargoyle to observe a nearby target and poststrike reactions. Meanwhile, the MAV would broadcast the sensor information for relay to analysts for assessment. Later, the MAV could reposition for enhanced poststrike collection or to observe another target. Moreover, ground forces in the vicinity of targets could deploy a MAV to relay poststrike imagery for BDA during attacks without the soldiers directly observing the target, thereby reducing the soldiers' exposure to hostile forces. At the time of this study, DARPA had plans to perform flight demonstrations of the MAV in 2003.[36] A final unattended sensor possibility uses deployable ground-based sensors. Vietnam-era US forces successfully employed these kinds of sensors for targeting, and contemporary analysts could use several types of modern ground sensors to conduct assessment.[37] Aircraft could deploy passive or active sensors prior to attack for targeting and assessment. The sensor capabilities include passive acoustic, seismic, or electromagnetic monitoring; active seismic and electromagnetic imaging; and effluent monitoring.[38] DARPA is currently investigating the capabilities of these sensors to determine the effectiveness of attacks against underground facilities, a particularly difficult class of target for current BDA imaging techniques.[39]

Employing unattended sensors affords unusual employment configurations. The Microglider concept's capabilities would allow it to continue to observe a target until after the debris cloud clears the target and all the strike aircraft departed the area. The MAV device would gather information in urban areas from vantage points otherwise difficult to obtain. Ground sensors would enable persistence in reporting attack damage and poststrike enemy reaction. These ground sensors could also gather types of information not commonly available from most of the other sensor configurations, such as seismic, acoustic, and effluent data.

However, the downside of employing unattended sensors for BDA is considerable. Although engineers have experimented with deploying an unattended sensor from a UAV for seismic monitoring, the delivery of these sensors remains a troubling aspect for this concept.[40] If operators cannot deploy these sensors surreptitiously, their use may alert the adversary to an impending attack. Even if developers overcome the deployment issues, the question of how to relay sensor information remains. The Microglider and MAV systems could broadcast information back to the deploying entity for analysis, monitoring, or relay. However, ground-based sensors would almost always require a relay system. Deploying numerous ground sensors to ensure survivability and coverage through redundancy makes sense. However, bandwidth demands for enough sensors to cover more than a few targets would quickly overwhelm an already overtaxed communications architecture.

Apparently, developers have proposed a variety of technological approaches for getting data to support real-time BDA. However, all potential solutions have characteristics that limit their utility or the total number of targets they can observe. Furthermore, the services would have to invest a considerable amount of time and money to develop, field, and validate any of these technological solutions. While each solution might gather the desired BDA data in real time, it is of marginal value unless procedures exist to adequately exploit the data.

Procedural Solutions

The intelligence and operations communities continuously struggle to improve current BDA procedures to get accurate assessments to users faster. Although many of these changes exploit advances in technology, the principle innovations present in the following concepts involve changes in the procedures analysts use to perform and disseminate BDA. Potential changes vary in scope from fine-tuning the current procedures to transforming a majority of the process. These alterations include creating a shared BDA database, automating BDA analysis, conducting BDA by representation, performing BDA by exception, and focusing on operational-level effects. These modifications would provide a variety of ways that analysts could gather, process, and disseminate BDA information faster and more accurately. Nonetheless, each potential solution entails downsides when examined with respect to airpower planning and execution.

Common Database

In one innovative approach, analysts could use a common BDA database to perform distributed BDA processing. The DIA and theater intelligence centers are developing and maintaining a database of targeting information called the Modernized Integrated Database (MIDB).[41] The technology exists for analysts to use a system that pulls information from the MIDB at the beginning of a conflict and updates the database to reflect current target BDA.[42] With this system, analysts could conduct distributed BDA, updating the shared database by entering information to reflect their analysis. Other analysts and operators could access the database whenever desired to determine up-to-the-minute assessments of the operational status of targets. Thus, people in national, theater, and AOC intelligence cells would have access to real-time BDA from a common operating system.

By creating a rapid, distributed processing system using a common BDA database, analysts could significantly enhance the process of combining data from disparate sources or conducting Federated BDA. By placing all information on a given target within a database referenced to a common numbering system, intelligence personnel could access the most up-to-date analysis. Theater personnel could efficiently and effectively access the analysis that experts conduct outside the theater. BDA information from outside the theater would not languish in an inbox waiting for a theater representative to process or enter it into a regional database. Theater intelligence personnel would have a common point of reference for discussions with personnel from outside the theater regarding poststrike status. A common database would enable theater intelligence personnel to quickly develop a functioning database early in a crisis against an unanticipated adversary. Although a common database would do nothing to reduce the time analysts need to interpret the data during the BDA process, it could notify them when the data is available. Analysts could perform their work with confidence knowing that they have the latest data. Thus, a common database would increase BDA timeliness while ensuring accuracy. All of this is possible today. The intelligence community possesses the capability and technology required to implement a common database if desired.[43]

Although the capability to establish a common targeting and BDA database exists, those responsible have not yet implemented this procedure for several reasons. To ensure accuracy and credibility, the DIA and theater intelligence centers want to maintain control over the database.[44] In some respects, such an arrangement makes sense. As the theater commander's responsibilities include BDA determination, the theater intelligence center is the logical choice for updating the database. However, the Air Force and other components gather specific information they would need to enter into the database, and if the components must wait for the theater centers to enter the information, the information reflected in the database may not be timely enough to support ongoing operations.[45] Additionally, engineers are striving to prove that a system can selectively pull secret-level information from a database that also contains information with a higher classification level.[46] Without this capability, intelligence personnel would have to produce a separate edition of the MIDB at the secret level, which would be a time-consuming, laborious process that could slow the initial establishment of a BDA database and may lead to inaccuracies.

Automated Analysis

Intelligence organizations might also try to automate BDA analysis and dissemination to get information to users faster. Using a system similar to the previously mentioned common BDA database, system designers might develop a system to receive sensor information and correlate it with current MIDB. Sensor data broadcast by LOS or satellite relay would automatically feed into the BDA system. As the system receives information, it would analyze the poststrike EO/IR imagery or other sensor data using complex algorithms to determine the nature of damage inflicted and accuracy of attacks. Alternatively, developers might design a system to assemble automated analysis conducted onboard the BDA sensor platform into a database. Whether the analysis is automated at a centralized location or on the sensor platform, the system could broadcast BDA updates to operations and intelligence personnel for action.

An automated system might eliminate delays created by human analysts and the current dissemination process. Automation would remove delays caused when the BDA information sits in a queue waiting for analysts to evaluate the information. These delays occur due to incompatible time zones between the theater and the analysts or because the sheer volume of data requiring interpretation overwhelms the analysts. An automated system would enable intelligence and operational personnel to access BDA based on up-to-the-minute sensor data. During high-volume operations, planners and aircrews could make informed restrike decisions earlier with automated analysis. Aircrews might benefit from automated analysis using data gathered from sensors onboard strike aircraft. In high-threat environments or demanding situations, aircrews could benefit from automating their sensor's information into usable, first-cut BDA.

In spite of an automated system's potential, numerous detractions exist with automatic analysis. For an automated analysis system to succeed, intelligence and security personnel must first overcome the hurdles preventing them from adopting a common database. Developers would have to design a system capable of autonomously interpreting BDA sensor information to determine target damage. As previously mentioned, DARPA already stepped away from this approach at least once.[47] If system designers overcome these difficulties, further issues remain. As the theater commander is the determining authority for BDA, each theater might develop disparate criteria for systems engineers to incorporate. The theater staffs would likely see BDA automation as threatening their power to determine how a campaign is progressing. Competing analysis created difficulties during the Persian Gulf War, and theater staffs would almost certainly resist this shift in analysis responsibility. Theater personal are liable to challenge both the accuracy and accountability assertions by arguing that the automatic system might increase timeliness but only at the expense of accuracy.

Representative Bomb Damage Assessment

In another approach, analysts might streamline the processing and dissemination system by conducting BDA on a representative portion of the targets and extrapolate those findings to get an overall assessment picture. Due to the accuracy of current precision-guided weapon systems, examining each individual weapon impact may be overkill. Rather, analysts could perform BDA on a small number of targets representative of the whole group of targets struck during a large-scale attack. By observing the selected targets during and after strikes, analysts could verify the desired effects. In this manner, the analysts could quickly extrapolate the overall effects without becoming inundated with poststrike data. Furthermore, they could develop a baseline from previous strikes to analyze comparable strikes during the conflict. In this manner, analysts could provide BDA to complement the developing concept of predictive battlespace awareness.

The concept of intelligence personnel extrapolating BDA from a representative slice of the total number of strikes offers the potential of significant rewards. Intelligence organizations could overcome the limits of too few sensors or too much raw data. Analysts could concentrate their BDA efforts on data from current sensors to increase precision and avoid becoming inundated. If designers build a process to baseline the BDA while accurately accounting for the context of the attack (i.e., detonation location, target location, weapon type, fusing, angle of weapon impact, etc.), analysts might be able to predict damage. With this information, intelligence personnel might be capable of accurately predicting the effects on targets. Furthermore, they may, on occasion, be able to extrapolate higher-order effects if the model contains enough fidelity.

While extrapolating BDA would yield notable benefits, the idea has negative considerations as well. Current theater commanders continue to require visual confirmation of each aircraft or tank destroyed so they can report these results to their superiors.[48] They frequently evaluate the campaign's progress based on the number of targets destroyed. Analysts may not be able to convincingly report a total number of a type of target as destroyed if the analysts are extrapolating BDA. Furthermore, interpreters may face a larger challenge from the amount of detailed information required to ensure accurate extrapolation than they would have conducting detailed BDA. If the analysts use a baseline, they must still gather quite a bit of information to model the effects from the detonation parameters. Changing context and advances in technology may require modelers to build a new baseline frequently. Intelligence personnel may struggle to coordinate information on the target with the reported strike parameters. Finally, the potential is great for intelligence centers to develop a significantly flawed overall assessment based on the extrapolation of a few overly optimistic or pessimistic assessments. Although this procedure may speed up the BDA process, accuracy remains a concern.

Bomb Damage Assessment by Anomaly

The concept of conducting BDA by anomaly offers another opportunity to assess data quicker. Designers could create a system that would monitor the location of targets scheduled for attack in the ATO and task BDA sensors accordingly. The sensors would observe the strike locations to confirm that the expected results transpire at those locations. They would relay information to verify that kinetic weapons detonate properly or that nonkinetic attacks create the effects desired. The BDA system would analyze this information and immediately notify intelligence or operations personnel of anomalies requiring further analysis or calling for tactical decisions. The system would archive sensor information along with correlated ATO targets, which would enable analysts to conduct follow-on analysis if required.

Conducting BDA by anomaly also presents new opportunities for improving the BDA process. Analysts could become more responsive by devoting a majority of their efforts to targets with strikes identified as anomalous. By not focusing on confirming the multitude of successful strikes, intelligence personnel could shift their emphasis from tactical to operational-level assessments. Even when scrutinizing numerous, simultaneous attacks, analysts could keep pace and conduct timely analysis by attending to anomalies. With this procedure, conducting BDA by anomaly would accommodate large-scale, simultaneous attacks in real time without excessively tasking the BDA process.

The concept of conducting BDA on anomalous strikes is limited in a few ways. One problem may be determining what defines an anomaly. Once again, theater staffs will want control over what defines an irregularity, while the intelligence agencies at the national level will want to develop a universal standard. As in predictive analysis, analysts must gather sensor and strike reports to collate with targets. The process must also determine the feedback expected from each target scheduled for attack to establish if any strikes are uncharacteristic in nature. All the while, this system must adapt to mission changes and cancellations. Otherwise, the procedure will highlight targets not struck for analysis and might neglect to observe new targets.

Operational-Level Bomb Damage Assessment

Finally, analysts could stop conducting BDA on each individual target and focus instead on the overall effects of the attack. Currently, analysts focus on determining the result of each individual weapon and try to extrapolate from these effects to determine the impact on a larger target set or system. However, in the proposed process, analysts could avoid a tendency to resort to reductionism. Rather than attempting to construct a higher level of analysis by assembling the assessments of individual strikes, the analysts might direct their efforts towards determining if the attack achieved the desired effects. For instance, rather than trying to determine how much each strike damaged an electric node, analysts would look to see if the power is off in the desired area.

However, higher-order analysis may not satisfy the theater intelligence or operational fidelity requirements. Joint force commanders (JFC) will probably continue to want to make decisions based on assessments of the number of targets (e.g., tanks or aircraft) destroyed, rather than relying on the fact that the division or airfield is not operating. Although Airmen may turn to effects-based targeting in employing airpower, commanders will continue to direct analysts to assess levels of physical destruction. Consequently, as long as the decision makers in the process demand pictures of targets destroyed, the procedures will continue to attempt to satisfy these demands.

All of the foregoing procedural propositions attempt to increase the speed of the BDA process. Most of these procedural changes take advantage of current and nascent technology, but the intelligence organization may need to change their structure to take advantage of any new procedure.

Organizational Solutions

A review of the current organizational structure for BDA suggests that intelligence and operations agencies have not organized to get accurate assessments to users as rapidly as possible. Therefore, restructuring the organizations that conduct BDA may improve the timeliness of assessment. Intelligence system operators and analysts often impede the BDA process by setting priorities driven more by organizational agendas than user needs. Overcoming some of these effects, while accommodating others, may better enable timely, accurate analysis. Possible changes include assigning the analysts to centralized or decentralized intelligence organizations by moving them into platform aligned analysis centers or putting them directly inside the cockpit. Organizational innovations may also require technological and procedural enhancements, but the primary focus of these innovations are organizational. However, as in the other sections, the organizational solutions proposed in this study are not free of liabilities.

Centralized Analytical Center

One potential organizational configuration would concentrate all analysis personnel at a central location such as the NMJIC. This arrangement would make it easier for intelligence agencies to standardize and manage the process. With a dedicated, centralized analysis organization, analyst training levels may improve because the analysts would be full-time staff rather than personnel deployed to a theater during a crisis with little recent and relevant training. This configuration would also foster interaction within the organization by possibly generating synergies within the analytical process.

Creating a standing centralized BDA analysis center for all theaters may provide sizable benefits. Designers would no longer need to develop a system to coordinate timely analysis using a federated process. Instead, they only need to build an intelligence system capable of disseminating the analyzed BDA. In contrast to relying on a federated process with associated delays due to broadcast requirements and time-zone differences, the centralized analysis center could manage the analytical processes more efficiently and disseminate information of consistent quality to field units. The sole analysis center would have a larger voice than the competing theater BDA cells currently possess when advocating for personnel and funds. The national center could articulate requirements and would be able to mandate changes more effectively than the current system. A centralized center would standardize BDA criteria and procedures throughout all theaters. Analysts would no longer deploy on an ad hoc basis to increase the capacity at the theater intelligence cells. Not relying on these potentially untrained or inexperienced personnel would increase analytical competency while reducing operations tempo and deployment expenses. A centralized center would produce consistent quality BDA from dedicated specialists who are comfortable and proficient with the process.

Despite these advantages, centralizing the BDA process would also have shortcomings. It would effectively remove the theater commander's control over the BDA process, which proved to be important in the Persian Gulf War. It would also increase organizational disconnects between the theater and national-level agencies because of competing priorities. The national center's priorities, while attempting to account for the needs of all theater intelligence centers, may also have to satisfy national-level requirements. As a result, a national BDA center may not be able to meet the theater intelligence centers' requirements fast enough. Conversely, anytime the theater intelligence centers do not have timely BDA, they would likely blame the national BDA center's priorities, even if the delay is caused by other reasons such as lack of sensor data. Additionally, the centralized BDA cell would have to coordinate with the theaters to schedule and receive BDA data from theater reconnaissance assets. This may pose problems if the theater needs to use these assets for other tasks. Since BDA would not be the theater's responsibility, the theater intelligence center may want to use scarce resources for gathering targeting data instead of BDA data. Consequently, while centralizing the BDA process might make the analysis aspect of BDA more efficient, the central organization might have to struggle to gather the data necessary and would not be as responsive to the needs of the theater.

Distributed Analytical Centers

Distributing analytical centers to the theater or component level, such as the JFACC, is another organizational alternative to the current system. Under this plan, imagery analysts and other specialists would move from the national level to theater or component intelligence cells. Analysts would become familiar with their region, which would result in increasing their analysis capability and responsiveness. Intelligence personnel could develop contacts across and within components prior to the outbreak of a crisis. These points of contact could foster greater cross-component cooperation and integration. As a result, the AOC intelligence personnel would become comfortable with the processes in their region, familiar with the theater, and highly productive at the outset of a crisis. By distributing the analysts during peacetime, they would become familiar not only with the intelligence organization and processes but also the component and theater region, personnel, and procedures. Trained analysts would be available in-theater responding promptly to decision makers' desires. Theater or component BDA cells would not need to coordinate with a federated process, thereby reducing possible communications problems and preserving local control of the process. If an adequate number of analysts are available in the AOC, they might be able to take advantage of assigned assets, as well as feeds from outside assets, to conduct rapid BDA on site. Furthermore, collocating analysts with planners in the AOC would almost certainly make analysts more aware of what planners want strikes to accomplish.

In spite of these benefits, distributing the analytical centers would have drawbacks. Most of the analysts for national intelligence-gathering systems currently work to fill national-level intelligence requirements in national-level organizations. If these analysts moved to regional centers, either the national mission support would be reduced, which is not likely to happen, or the services would need to train many more analysts for these systems. The services are already short on experienced analysts and distributing some of those analysts to a level capable of handling the theater or component requirements would most likely exacerbate the situation. Additionally, the Air Force has attempted to reduce the number of personnel required to operate an AOC and dedicating the analysts to the AOC would notably increase personnel levels. Finally, if the components receive the distributed analysis centers, the theater intelligence centers may not have enough personnel for their purposes and would once again lose control of the process. Consequently, it appears a distributed system would be more responsive, but the number of analysts needed may make it impractical.

Collection Platform Aligned Analytical Centers

Alternatively, rather than orienting on geographic basis, the Air Force could create an analysis structure based on a collection system. Intelligence processing centers would conduct BDA in locations that receive all the information from a given platform or sensor system. Each collection system would broadcast raw, onboard sensor information to one or two sites, presumably located in the United States, for processing. The Air Force might locate the processing, analysis, and operational sections of the sensor or weapon system in a place that increases each platform's overall responsiveness. Each location could specialize in interpreting the specific kinds of information its sensors produce, thereby fostering increased analytical competence and leading to system optimization. This system would resemble a conglomeration of systems similar to the existing U-2 or Global Hawk processing system.[49]

A different structure organized around specific collection platforms also offers to make the BDA process more responsive. In this scheme, analysts could become specialists in interpreting data from a specific platform. Because they could all conduct their analyses in one or two locations, personnel would gain experience from operations occurring anywhere in the world. Consequently, efficiency and effectiveness in analyzing sensor data might dramatically increase. With one or two intelligence cells responsible for working with data from a particular platform, those cells would likely foster greater cooperation between themselves and the platform operators and system processors. The BDA cells could also stay better attuned to schedule changes in the sensor platforms. Therefore, this configuration would increase sensor utility and ensure that the platform responds to the needs of each cell.

However, an organizational structure built around platforms has limitations. Once more, the theater commanders would lose their ability to oversee the BDA process. As there would be multiple users of this BDA, the national, theater, and components would likely differ in opinions on priorities and make competing demands that the BDA cells may not be able to resolve. The cultures and priorities of the BDA organizations could conflict with those of theater or component organizations since BDA organizational responsibilities are not aligned with those of organizations using the BDA to make decisions. Although the platform-based structure might ease the process of gathering the platform sensor data, this structure may not be responsive enough for theater or component users.

Cockpit-Centered Bomb Damage Assessment

One final organizational change mentioned in passing within the previous sections would entail moving phase one of the BDA process to the cockpit. Numerous companies and service laboratories are tackling the challenge of delivering imagery to aircraft in flight for target recognition.[50] A plausible extension of this development would involve transmitting sensor information to aircraft during and after an attack. The aircraft would receive this information directly from sensors that the aircraft deployed or relayed from other reconnaissance systems. Aircrew would determine the initial BDA and could restrike if necessary and able within the established rules of engagement (ROE). For sensors deployed from the aircraft, the aircrew could review the sensor information when able, comment on the data, and transmit the information to other aircraft or the AOC while in flight. Analysis centers on the ground could still conduct BDA and validate mission effectiveness.

Conducting initial BDA in the cockpit would have several advantages. If BDA sensors could be employed with the aircraft, planners would not need to coordinate collection assets with the strikes. Without intervening institutions conducting initial analysis, this structure would reduce or eliminate the friction associated with communications problems and conflicting organizational priorities and agendas. This arrangement would get first-cut BDA immediately to aircrews, which would allow them to rapidly restrike targets.

However, obstacles exist that diminish the prospective benefits of conducting BDA in the cockpit. This arrangement could increase aircrew workload considerably. If the process is not automated, pilots may require training to interpret complex data. Planners would need to ensure that pilots understand the desired effects of the strike. Considering the current planning process, this is a potentially daunting task for everyone involved. When developing ROE, the theater staff and the AOC may disagree about when a restrike is needed. Finally, the theater staffs may think that aircrews conducting BDA in the cockpit infringes upon the theater intelligence center's mission and authority. While BDA in the cockpit would get first-cut data to a critical user faster than any alternative approach, the technological and bureaucratic constraints may make it impractical.

Summary

After considering many possible alternatives, it appears technology offers some innovative solutions for acquiring and distributing the data necessary for BDA. However, without adequate processes to evaluate the raw data and develop usable BDA, even the best sensor data is of little value. Moreover, without a responsive organization capable of using the BDA, the best analysis will stack up unexamined just like poststrike photos in Vietnam. Consequently, anyone attempting to improve BDA support for air operations must take into account the technological, procedural, and organizational facets as well as their interrelationships. Thus, intelligence and operations personnel should pursue a combination of some or all of these solutions to significantly improve BDA timeliness without sacrificing accuracy.

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Chapter 5

Implications for Airpower

Where judgment begins, there art begins.

—Carl von Clausewitz

The truths of war are absolute, but the principles governing their application have to be deduced on each occasion from the circumstances, which are always different.

—Winston Churchill

What does the future hold for BDA? Which, if any, of the proposals this study has identified will the services or the Joint Staff implement? How will these solutions and correlating benefits affect how air operations are planned and executed? These questions are answered by drawing on information in previous chapters, current literature, and interviews with individuals who work various jobs within the BDA process.

This chapter explains the effects real-time BDA will probably have on future airpower planning and execution. To accomplish this task, two distinct themes are developed. First, this chapter details the improvements the joint community and the Air Force are likely to pursue in BDA over the near term and discusses how those improvements will affect airpower planning and execution. Second, this chapter identifies recommended capabilities that the Air Force and others should pursue, and it explains how moving in those directions might influence airpower.

Near-Term Bomb Damage Assessment

The services and the joint community seem poised to implement numerous modest changes to BDA in the near future. These changes incorporate a mixture of technological, procedural, and organizational improvements. However, the service component and the joint community are taking different approaches to improve BDA. Noticeable differences of the objectives are expressed in the charters of the Joint BDA Joint Test & Evaluation (JBDA JT&E) and the Air Force Command and Control and Intelligence, Surveillance, and Reconnaissance Center (AFC2ISRC). The JBDA JT&E is focusing on how to improve the ways that BDA supports the JFC.[1] Conversely, the AFC2ISRC seeks to ensure "necessary information moves from the sensors to the decision makers to the aircrews in the best format to increase survivability, lethality and mission effectiveness."[2] Intelligence organizations probably will not implement the changes in a completely holistic manner because of these differences in emphasis.

However, each of these adaptations will affect airpower employment and the interactions of all of these changes may produce effects that are greater than the sum of the improvements when considered separately.

The services will most likely purchase more UAVs. DOD projected spending $4.2 billion on UAVs in this decade.[3] At the same time, the services will endeavor to reduce the UAV bandwidth requirements or increase bandwidth capacity. Consequently, the JFACC will likely be able to simultaneously employ approximately twice the number of UAVs than are usable today. However, designers are developing improved sensors for these UAVs, which will likely cause continued conflict concerning price and bandwidth.[4] In the near term, UAVs will provide real-time BDA of three to six areas at any given time. As in the past, planners may be willing to sacrifice sensor fidelity for an increase in the number of vantage vehicles, but planners will still need to prioritize target coverage. The AOC will have to choose between emphasizing the use of UAVs for surveillance to detect emerging weapons or BDA for strikes. If planners use UAVs to identify targets, they can also obtain BDA information on the target they are surveilling if the UAV concept of operations includes this task. High-threat environments will likely preclude regularly using the current generation of UAVs unless commanders are willing to assume considerable risk. As a result, only a few of the highest priority strikes, not in high-threat environments, will likely receive quick BDA from UAVs.

For high-threat environments, the services are developing munitions that aircraft can deploy from outside of the threat radius. It is quickly becoming obvious that those munitions need sensors to relay at least telemetric data for strikes beyond aircraft observation. The services will likely develop a system capable of gathering guidance and targeting telemetry from these weapons. Planners will need to ensure that enough of these weapons and aircraft capable of employing them are available for execution of the intended air operations strategy. The desire to gather telemetry on a strike will dictate what aircraft and weapon schedulers select for an attack. Therefore, BDA considerations may override targeting priorities in extreme situations. Although this data will provide valuable information, the AOC will frequently need to infer from the data if the strike achieved the desired effect. Consequently, Airmen will have an indication of the effect but will most likely want additional BDA data to confirm these inferential assessments. This will delay the process while waiting for other data. The AOC may find it difficult to convince the theater intelligence center of the results of a strike based solely on telemetric data.

On the procedural side, the services will implement some modifications that will improve the process. Eventually, the joint community will implement a common database that reflects the theater intelligence center's assessment of relevant targets. The services will embrace the common database to ensure they have access to the theater intelligence center's information during operations. However, the theater staff will maintain the responsibility to produce BDA, and consequently, they will not delegate authority for the components to update the database. However, personnel within the AOCs will want to keep track of what they consider the actual status of targets. Therefore, they will need to maintain an AOC version of the database or continue to track target status with computer spreadsheets and include BDA data such as imagery, video snippets, and aircrew mission reports with the target folders. The AOC will perform its analysis on available information and call it something like *battle damage indicator* (BDI) or *bomb impact analysis* (BIA), which are terms emerging to describe activities conducted at the AOC while avoiding conflict with the theater intelligence centers over responsibilities.[5] The AOC will use BDI or BIA to answer two fundamental questions without waiting for the theater to update the common database. Did the munition hit what was intended? Did it function properly? The AOC will use BDI or BIA to inform the theater intelligence center of the effects the AOC thinks the strikes achieved. The process will be similar to today's procedure only incrementally faster.

On the organizational side, the Air Force will probably develop intelligence processing centers within the continental United States to reduce the AOC footprint. The processing center for the U-2 will serve as the model and starting point. It is conceivable the Air Force will collocate Global Hawk sensor data processing with that of the U-2. Intelligence personnel and planners will have one dedicated source for interpretation of theater-based, air-breathing sensors to reduce confusion concerning who to contact for processed information from U-2s and the Global Hawk. Furthermore, the Air Force will deploy a few analysis personnel to the AOC to interpret the information available from the processing centers, national-level systems, in-theater collection assets, weapon system videos, and aircrew mission reports. These intelligence personnel will likely be the individuals collecting and articulating the AOC's overall BDA picture. The planners and executers within the AOC will have local interpreters to determine if a strike achieved the desired effects without waiting for the theater intelligence center to publish the relevant BDA. Overall, these organizational changes will result in a moderate increase in timeliness through increased coordination.

Taken as a whole, changes across the three spectrums will improve the BDA process. These changes will marginally increase the flow of information, reduce delays, and improve coordination. Conflicts between the AOC and the theater intelligence center will continue to arise when the AOC's BDI or BIA do not agree with joint task force BDA. Planners will only be able to conduct real-time BDA on a few targets. Consequently, their plan must account for this limited amount of feedback, and that may heavily influence the attack plan during the first few days of a campaign. If they want the ability to restrike a target with the same strike package, they must reduce the number of priority targets scheduled corresponding to the number of desired restrikes. The strike package will need to withhold munitions for a restrike, thus increasing the number of strike aircraft required in a package or reducing the number of targets each aircraft can strike. The strike package can expend these munitions on another target if desired once the AOC or aircrew determines a restrike is not necessary, but the additional target will not likely be a high-priority target. Planners will need to ensure they schedule high-priority targets for attack with certainty on a given mission rather than for left-over munitions.

In low to moderate threat environments, the AOC will have access to real-time EO, IR, or SAR BDA on a few high-priority targets. In these lower-threat environments, the AOC may control these aircraft and dictate restrikes. Consequently, the AOC may have the information necessary and the desire to exercise centralized control over limited numbers of specific aircraft as they conduct actual strikes. There lies a potential hazard. The AOC might be tempted to place aircraft in untenable positions while analyzing the BDA information. However, since real-time BDA is limited to a few strikes, the AOC might miss opportunities to gather the majority of the BDA data. The missed information might be from the effects of small weapon detonation and, in the future, nonlethal attacks, as well as attacks against mobile, emerging, hardened, or deeply buried targets. Thus, ubiquitous, real-time BDA does not appear to be likely in the near term.

Recommendations

The near-term solutions, while beneficial, do not optimize BDA for employing airpower to its greatest effect. This suboptimization reduces airpower's potential. The intelligence and operations communities should pursue two improvements to more fully exploit this potential. First, designers should develop methods for operators and analysts to collect data in real time on every strike. Second, analysts should move away from processing information on every target and, instead, determine the effect on a target system with a holistic process. To conduct these operations, the USAF may need to adapt its intelligence structure.

The military should pursue the capability to gather BDA data real time on every target to avoid losing transitory data. To accomplish this feat, the services must explore, develop, and field multiple sensor capabilities using new or existing hardware to gather more types of BDA data than EO. The designers should modify current strike aircraft and design new aircraft to gather BDA data. The services should develop munition sensors with a system to gather and transmit BDA data back to the cockpit or the AOC for attacks beyond aircraft sensor reach. When procuring and employing UAVs to conduct surveillance and reconnaissance, the services should not neglect obtaining the ability to capture and relay the effects of attacks back to the AOC.

The information from these aircraft, munition, and UAV sensors should feed into a system in the AOC to automatically categorize and correlate the information with the desired delivery platform and target. Furthermore, researchers should continue to evaluate the potential for an automated damage recognition capability to provide real-time, hit-miss indications. This capability would not supplant BDA, but it would be a piece of valuable information for identifying anomalous attacks for follow-on analysis.

However, intelligence and operational personnel should avoid scrutinizing every piece of BDA data in near real time. Conducting real-time BDA on every strike may not be feasible or even necessary. Instead, the AOC should conduct BDA on a representative sample to confirm munition and delivery effectiveness. The AOC analysts should also evaluate reports of anomalous strikes to determine whether a restrike is needed. These assessments would identify areas the planners should examine to determine how much the anomalies have hindered efforts to achieve operational objectives. To encourage analysts to accept data from sensors other than EO, intelligence personnel should become more comfortable with multiple types of sensor data and try to incorporate this information into their analyses and, thereby, the decision-making processes that those assessments support. Finally, the intelligence personnel within the AOC should concentrate on evaluating whether airpower is achieving the desired objectives. These efforts may require access to other information, but rather than focusing on first-order effects, intelligence personnel should focus on second- and higher-order effects.

For these modifications to have their greatest effect, the intelligence structure must support these procedural changes. As the theater intelligence centers' priorities will continue to reflect their theater-level, campaign focus, the services must ensure the AOC and the service intelligence structure support BDA for the AOC. The Air Force should develop two or three processing centers within the continental United States to process and analyze BDA information. These centers should receive information from all available sources 24 hours a day when needed. Consequently, the services must train enough analysts and station them at these centers to filter and process the information for the AOCs. The services must staff the AOC with enough competent intelligence personnel to enable the AOC to perform the analysis previously described. The Air Force should organize BDA analysts to best evaluate the overall effects on a target system. This requires analysts to understand the AOC planner's intent. Therefore, the analysts will need to interact closely with those AOC personnel responsible for long-range and daily planning.

Two recommended improvements will provide numerous advantages over the present and near-term processes. Implementing these recommendations on gathering and processing BDA information as described will provide many benefits. Fleeting data from movable targets, targets deeply buried, or targets attacked with small munitions may be unavailable if not collected at the time of detonation. Without this information, the AOC may not be able to validate the effectiveness of attacks on these types of targets for several reasons. First, adversaries often haul away the wreckage of equipment destroyed in air attacks. Second, the nature of buried targets makes it difficult to determine their status after the fact. Third, the effects of small munitions may be imperceptible even when employed against visible structures or equipment. Because of this, planners may mistakenly stop or change methods of attack that are highly effective, or they may expend additional sorties against already affected targets, while wasting valuable resources and needlessly placing aircrews and their aircraft in danger.

Implementing these recommendations makes a second benefit possible: Air operations can adjust to dynamic changes quicker and effectively. By gathering the data immediately and scrutinizing a fraction, the AOC may eliminate the period between the occurrence and discovery of any systemic errors in air operations. Analysts would be able to ensure that weapons are affecting their targets as intended by exposing any weapons or delivery problems. Thus, the planners and aircrews may be able to adapt quicker. The AOC may respond appropriately to an anomalous attack swifter because of the rapid availability of BDA data. An informed decision to restrike is possible. The timely availability of BDA information may also help avoid the appearance of guilt by US commanders. With the speed and influence of mass media, rumors of errant strikes circulate rapidly. When commanders are unable to respond to these rumors immediately, the press and public often view their hesitation as efforts to stonewall the media. Prompt BDA information will enable commanders to quickly respond to charges that attacks have had collateral effects rather than needing to delay a response while waiting for information.

Implementing these recommendations could prove beneficial when the AOC relates the effects of air operation to the JFC's staff. Although counting numbers of targets destroyed may not be the preferred method of measuring effectiveness, the future will likely find JFCs' designating objectives that require counting targets destroyed to determine effectiveness. Therefore, gathering this information for the JFC will enable the AOC to provide timely and accurate information to the theater intelligence center. This will diminish the informational disconnects between the AOC and the theater intelligence center by fostering a common perception of the campaign's progress.

Finally, avoiding a tendency to focus on each weapon's effect holds many benefits beyond reducing analyst requirements. Current trends in information collection threaten to paralyze the analytical process by outstripping each center's processing and analysis capacity. As the small-diameter bomb promises to increase the number of targets each aircraft is capable of striking, the flood of BDA data from this increase in targets threatens to overwhelm any process oriented around the amalgamation of manual analyses. Freeing analysts to focus on the higher-order effects of target systems and the enemy as a whole offers an opportunity to focus on airpower's overall contribution to achieve the JFC's objectives. Planners may be able to determine the overall consequence of employing airpower rather than carrying out faith-based bombing and conducting a survey after the conflict is over.

Many intelligence officers with experience in the BDA process, when asked, will tell you there is a trade-off between timeliness and accuracy. You can improve one only at the expense of the other. This may be true using today's technology, existing procedures, and the current organization. However, making changes in all three facets of the BDA system offers the potential of a level of improvement that substantially exceeds the sum of the improvements taken individually. Not only is real-time, manual analysis during anything other than a small conflict absurd, without adding many more analysts in the AOC dedicated to BDA, the AOC will be unable to process the increased volume of BDA information available from one day before the next day's information begins to fill the queue waiting for analysis. Others may tout the need for real-time BDA on all strikes, but this is not a realistic approach. To optimize BDA for employing airpower in the future, we must pursue the ability to gather BDA information real time and conduct basic, real-time analysis on high-priority targets but concentrate on evaluating the higher-order effects of airpower.

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Glossary

Joint Bomb Damage Assessment Terminology

battle damage assessment. The timely and accurate estimate of damage resulting from the application of military force, either lethal or non-lethal, against a predetermined objective. Battle damage assessment can be applied to the employment of all types of weapon systems (air, ground, naval, and special forces weapon systems) throughout the range of military operations. Battle damage assessment is primarily an intelligence responsibility with required inputs and coordination from the operators. Battle damage assessment is composed of physical damage assessment, functional damage assessment, and target system assessment. (Joint Publication [JP] 1-02, *Department of Defense Dictionary of Military and Associated Terms,* April 2001, 50)

combat assessment. The determination of the overall effectiveness of force employment during military operations. Combat assessment is composed of three major components: (a) battle damage assessment; (b) munitions effects assessment; and (c) reattack recommendation. The objective of combat assessment is to identify recommendations for the course of military operations. The J-3 (operations directorate) is normally the single point of contact for combat assessment at the joint force level, assisted by the joint force J-2 (intelligence directorate). (JP 1-02, 76)

functional damage assessment. The estimate of the effect of military force to degrade or destroy the functional or operational capability of the target to perform its intended mission and on the level of success in achieving operational objectives established against the target. This assessment is based upon all-source information, and includes an estimation of the time required for recuperation or replacement of the target function. (JP 3-60, *Joint Doctrine for Targeting,* 17 January 2002, GL-6)

munitions effectiveness assessment. Conducted concurrently and interactively with battle damage assessment, the assessment of the military force applied in terms of the weapon system and munitions effectiveness to determine and recommend any required changes to the methodology, tactics, weapon system, munitions, fusing, and/or weapon delivery parameters to increase force effectiveness. Munitions effectiveness assessment is primarily the responsibility of operations with required inputs and coordination from the intelligence community. (JP 3-60, GL-8)

physical damage assessment. The estimate of the quantitative extent of physical damage (through munitions blast, fragmentation, and/or fire damage effects) to a target resulting from the application of military force. This assessment is based upon observed or interpreted damage. (JP 3-60, GL-9)

reattack recommendation. An assessment, derived from the results of battle damage assessment and munitions effectiveness assessment, providing the commander systematic advice on reattack of targets and further target selection to achieve objectives. The reattack recommendation considers objective achievement, target, and aimpoint selection, attack timing, tactics, and weapon system and munitions selection. The reattack recommendation is a combined operations and intelligence function. (JP 3-60, GL-9)

target system assessment. The broad assessment of the overall impact and effectiveness of the full spectrum of military force applied against the operation of an enemy target system or total combat effectiveness (including significant subdivisions of the system) relative to the operational objectives established. (JP 2-01.1, *Joint Tactics, Techniques, and Procedures for Intelligence Support to Targeting,* final coordination, 29 January 1999, GL-9)

Assessing Airpower's Effects

Capabilities and Limitations of Real-Time
Battle Damage Assessment

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