Landpower Essay

No. 04-8W
December 2004

An Institute of Land Warfare Publication

Nonlinear, Noncontiguous Operations and the Control of Indirect Fires and Close Air Support

by

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Operation Iraqi Freedom offers insights into the conduct of future wars. In the coming "savage wars of peace,"[1] units widely dispersed across disputed territory will be conducting a wide range of simultaneous missions, combat as well as peacekeeping. Opposition forces can appear at any time, operating against support and logistics elements as well as traditional combat units. In this new type of nonlinear war, all units, whether combat arms or combat support, must identify friendly and unfriendly forces on an ever-changing battlefield and operate communications systems with enhanced networking functions. The latter, combined with new capabilities in processing and integration, can radically transform the control of indirect fires (IF) and close air support (CAS).

Traditionally, control of IF/CAS resides with scarce highly trained specialists.[2] Even with innovative approaches by the Army and the Air Force to cross-train IF and CAS controllers they are numerically limited and may not be present everywhere they are needed. Paradoxically the awesome power of U.S. IF/CAS arms, if misdirected, can pose the greatest risk to U.S. land forces in future operations.

Given the Army's superiority in trained Soldiers and advanced equipment, only a foolish enemy will directly confront a combat unit. In unconventional—but in the 21st century, more prevalent—stability operations the Army will oppose small units of irregular forces, remnants of the previous government or those in opposition to the existing government combined, in some areas, with terrorists. To deal with these adversaries, platoon-sized or smaller elements will be needed to find, fix and destroy the enemy.

One of the paradigms of the Future Combat Systems (FCS)[3] is that the planned transformation will provide Army units the ability to operate within the opponent's decision cycle. This means the Army will act before the enemy can, assess the results of its action and act again before the enemy can react to the first action. However, small units employed in stabilization operations will find it difficult—and support units impossible—to unsettle foes who strike at a time and on terrain of their own choosing.

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The transition to stability operations reduces the advantages a combat unit holds in more conventional operations. At the conclusion of major combat operations, such as occurred in May 2003 in Iraq, U.S. forces which had been operating in large units began operating in small units, often dismounted from vehicles. The communications infrastructure down to the individual Soldier, which could provide rapid information dissemination down the chain of command and responses to emergency fire support needs, doesn't exist.[4]

In stability operations, an opponent will perceive the Army's Achilles' heel to be its logistics elements.[5] The Army is shrinking its logistical umbilical cord by delivering just in time just what is needed where it is needed. Logistics units travel in unprotected vehicles often filled with explosives or fuel. Logistics elements do not have the firepower, either direct or indirect, that a combat unit does. Scarce indirect fire control personnel are assigned to combat units, leaving logistics units without the capability to direct supporting fires.

Unlike combat units, logistics units are more prone to operate in patterns. If a unit establishes recognizable patterns, the enemy learns of those patterns over time and the advantage will shift. Ambushes can be planned and set, explosive devices laid, and even the local population warned to stay away from the coming battle. At the time and place of his choosing, the enemy can strike. Even a highly trained combat unit would face difficulties in dealing with such an adverse situation.

To the enemy the logistics tail must seem an opportune target: it doesn't have the firepower of a combat unit yet is rich in visuals, with burning trucks, American casualties and hostages for the news cameras. Ideally, the enemy attack will be detected before it can be launched. This may not always be possible, however, and in this event supporting fires are essential to disrupt the enemy's attack.

Spreading to more Soldiers the ability to direct fires will require a different approach, one that does not compromise precision or endanger friendly forces and civilians. Current technology integrated with appropriately trained Soldiers can provide direct fire support for all echelons. However, the current system does not and cannot support the Army when it is deployed in stability operations to provide security and humanitarian aid to a dysfunctional state.

The proposed system described in this paper is the Joint Observer Controller (JOC). The JOC uses an integrated design composed of readily available technologies to simplify and improve the observation and control of IF and CAS. Joint fires under this system are available to small units and logistics units.

Control Methods

Latency is the grit in the cycle of operational efficiency. Latency can be fatal in close combat. IF/CAS can shorten close combat and thereby reduce casualties. An overwhelming concern should be a significant reduction in the shooter-to-observer cycle.

The three general control techniques are command/response, control by assent and control by exception.[6] Command/response is the current method for controlling IF/CAS. This technique is rigid, consumes a great deal of time to execute and assumes that much, if not all, of the information relating to the event resides in the command node. Control by assent allows greater autonomy to the node responsible for executing the action. The command node must at certain key points agree with the course of action, otherwise the course will not be pursued. This method is typically faster than the command/response method and consumes less bandwidth. Control by exception provides even greater autonomy to the executing node. Unless the command node provides a countervailing instruction the executing node will continue on its course of action.

The latter two control methods assume that information is spread across the network and that reliable communications are available. They also significantly shorten the sensor-to-shooter cycle. With the advent of faster processors, larger memories and new communications systems, control by assent would more widely disseminate the benefits of IF/CAS to Soldiers who would not receive that support under the current system.

Current Indirect Fires/Close Air Support

The fires that potentially can support an Army unit are breathtaking in their flexibility, variety, amount and power. Organic units such as mortars can provide high explosive and smoke rounds. Field artillery can use cannon and rockets to engage personnel, bunkers or armor. Air support can come from helicopters, fighter bombers, gunships, attack aircraft, strategic bombers and, in the future, Unmanned Aerial Vehicles (UAVs). If the Army unit is close to a sea, then naval gunfire, airpower and missiles can be added to the mix. Controlling this torrent of weapons under enemy fire requires extensive training and exceptional skills.

Joint operations traditionally require that each service employing fire support or CAS provide its own controllers to the supported unit. Each of the services uses different procedures for controlling each type of supporting fire. A major problem in joint operations is the need to translate between different dialects. An additional complication is the sheer size of the control elements and the quantities of equipment needed to support them. Operations with allies add further complications. Currently an allied forward observer (FO) has no method for controlling U.S. IF or CAS.

Forward Observers

The Army trains its Soldiers in the rudiments of controlling indirect fire from tube weapons but relies on specially trained FOs in most other situations. Artillery and FOs are trained to quickly engage targets. A constant problem in nonlinear operations is relaying information so targets can be rapidly, safely and effectively engaged. Tactical intelligence must be rapidly developed to identify a viable target and the data passed to the guns before the target disappears.

The FO provides, in three separate messages, the elements of the call for fire (observer identification, target location, description and method of engagement). These messages and the responses from the Fire Direction Center (FDC) through voice links usually require several minutes to complete.

A call for fire (CFF) is a message prepared by the observer. It contains all information the FDC needs to determine the method of attack. It is a request for fire, not an order. Information is sent as it is determined rather than waiting until a complete call for fire has been prepared.

Regardless of the method of target location used, the normal call for fire is sent in three parts consisting of six elements (shown in the sequence in which they are transmitted):

- observer identification;
- warning order;
- target location;
- target description;
- method of engagement;
- method of fire and control.

The three transmissions in a call for fire are as follows:

- observer identification and warning order;
- target location;
- description of target, method of engagement and method of fire and control.

A break follows each transmission, and the FDC reads back the data. As might be expected, these transmissions can take several minutes, particularly if challenge-and-reply authentication is mandated.

Tactical Air Control

An Air Force air support operations squadron, which comprises about 20 enlisted tactical air control (ETAC) teams, is integrated into every Army combat division. Two-person ETAC teams as forward air controllers (FACs) guide pilots in attacking targets. Their role is critical in CAS operations, particularly when ground troops are closely engaged with the enemy.[7] However, these important teams might not be available where needed.

The following is an example of a mission that used voice to direct an air strike. U.S. Navy Captain William Deaver, commander of Carrier Air Wing 1 aboard the U.S.S. *America*, described a typical "talk-on" between a forward air controller and a pilot:[8]

FAC: Do you see the big crossroads in the middle of town?

Pilot: Yes, I do.

FAC: Do you see the church? To the northwest of the church is a large soccer field. Do you see the soccer field?

Pilot: Yes, I do.

FAC: That is one "unit" [an improvised measurement of distance]. From the center of town where the crossroads is, look to the south three units. Do you see that?

Pilot: Yes, I do.

FAC: Do you see the road running to the south of the large open pit?

Pilot: Yes, I do.

FAC: One unit to the west of that pit, down that road, is three buildings. Do you see them?

Pilot: Yes, I do.

FAC: Do you see the one with the red roof?

Pilot: Yes, I do.

FAC: That's your target.

This example shows what a highly trained FAC can accomplish with little equipment other than a radio.[9] The target was destroyed, but it took time over a communications link that might have been jammed by a more sophisticated opponent.

Other problems are associated with the current CAS control system.[10] CAS controllers in recent conflicts backpacked loads that exceeded their body weight over desert sands and in thin air through high mountains. CAS controllers are trained to distinguish which target is attacked by a particular aircraft by observing the aircraft's flight path and attitude, but tests conducted at the Army's National Training Center (NTC) at Fort Irwin, California, showed the CAS controllers had a success rate of less than 50 percent. This can be particularly dangerous; 20 percent of fratricide incidents result from a pilot misidentifying the target, 80 percent because the pilot was assigned a friendly force as the target. The average time from a CAS aircraft arriving on the battlefield to its dropping ordnance was 35 minutes. In one-third of cases aircraft waited so long they had to return to base without expending their weapons. The commander's intent with CAS was achieved only 27 percent of the time in the simulated missions.

Commanders' Observations

Operations in Afghanistan and Iraq highlight problems with the traditional fire control methods. Major General Franklin Hagenbeck, commander of the 10th Mountain Division during Operation Anaconda (an attempt to squeeze al Qaeda's mountain strongholds), has written:

> There were not enough GFACs [Ground Forward Air Controllers] or ETACs in [the] inventory to support every maneuver unit. . . . This war became platoon fights separated by distances in very rugged terrain with too few ETACs to go around. . . . On the first day of the operation, one platoon of 1-87 IN [Infantry Battalion] fought all day. That platoon happened to have the battalion commander and an ETAC in it. That night the ETAC was extracted. For the next twenty-four hours until we could get the ETAC reinserted, not even the battalion commander could call in precision fires. What happens if the ETAC is injured and has to be medevaced, or is killed?[11]

Logistics units amplify this concern. Often isolated from combat troops and traveling in unarmored trucks carrying explosives or fuel elements, supply units are vulnerable to ambush and are high-value targets warranting considerable effort by the opponent.

Major General William Webster, the 3d Infantry Division commander, notes that in the Iraq war,

> there were one or two [Air Force ETAC teams] available for any battalion at any one time, and those were just the combat battalions. If you look farther to the rear now, or elsewhere in the division, our support brigades also need the ability to deliver joint fires, because of things that may happen that are not in the forward area.[12]

As a partial solution to the problem of limited numbers, the 101st Airborne Division (Air Assault) is training "joint fire control teams," multiservice troops trained to call in strikes from air, sea or ground weapons.[13] These activities are increasing the number of personnel trained to call in indirect fires as well as CAS. These increased numbers still will not solve the problem of providing support to small units.

An Opposing Observation

Objections have been raised to changing the current CAS system, a system that has performed well in the two wars with Iraq. Proponents of current CAS procedures note that U.S. forces in those conflicts enjoyed an abundance of CAS, so much so that air assets could be on target within five minutes of a request for CAS.[14] The U.S. military seeks to minimize the costs of close combat and would avoid it entirely if the enemy could be destroyed before contact is made. This capability has been honed to an impressive pitch, with strikes occurring within close proximity of friendly forces.[15] The ability to guide close air attacks without excessive risk has been due, in large measure, to the highly skilled ETACs dedicated to this single, complex, extremely demanding task.

These observations are quite true when limited to the combat phase of the Afghanistan and Iraq campaigns. They have not been true in the stabilization phases. Enemy forces attacking small units have been able to inflict casualties and damage before a significant response can be marshaled.

Adaptation to a new and hostile environment requires new structures and new behaviors. Technology combined with training and new organization can bring the advantages of close indirect fire support to more elements than have been previously supported.

The Joint Observer Controller (JOC)

The end result of military Network-Centric Operations (NCO)[16] should be the ability to employ Air Force, Army, Navy and Marine fires in support of the mission. The primary focus is shortening the kill chain and facilitating the synchronized flow of relevant information by extending the Global Information Grid (GIG)[17] to the observer/controller. FCS units will conduct rapid, integrated and near-simultaneous operations. This type of fighting will put a premium on identifying friendly and unfriendly forces in a combat area, communicating long range and enhancing networking capabilities.

Quick reaction to targets is essential to operating within the opponent's decision cycle. The ability of joint fires combining their individual capabilities to strike the appropriate foe in the close and deep battle will enable the commander to efficiently control the fight. As the Army transforms, the importance of shortening the kill cycle increases. FCS relies on precision fires that in turn rely on accurate actionable intelligence.

To provide the ability to control IF/CAS the military will require JOCs who are so numerous that small units can be supported and capable of directing fire support from all three services. The JOC will be equipped with an integrated system of commercial off-the-shelf equipment (COTS) which simplifies the process of controlling CAS and indirect fire. The system will be designed for simplicity of use: the JOC will not require the long training period current controllers require. The proposed system architecture is shown in figure 1.

Design for Aided Fire Support

A number of methods are used to direct IF/CAS. To keep the design simple the polar plot mission was selected as the system requirement. A polar plot mission mandates that the observer's location must be known to the FDC. The observer sends the target direction, distance and vertical shift (how far the target is above or below the observer).

The proposed system uses items that are commercially available. In the proposed system, the elements are integrated, designed to eliminate mistakes and provide "one push support" in which operator interactions requesting support are minimized. The kill chain time would also be shortened by employing command by acceptance and more intelligence at the nodes. Higher commands could still set priorities and cancel attacks, but the information needed for engaging the enemy would be quickly and efficiently sent to the shooter.

Hardware Platform. Computational power continues along the lines proposed by Gordon Moore, one of the cofounders of Intel.[18] Microprocessors operating at 1 to 3 Gigahertz (GHz) are available, which would mean that between 250 million and 750 million instructions per second could be executed. Processing the complex geometrical relationships needed by the JOC can be performed in real time by handheld computers. Graphic accelerators building images from databases can generate images for the operator and guide him through the control process. The amount of memory available in consumer applications is astounding.[19] Multiple billions of bytes provide storage space for maps, images and databases, the foundations for real-world modeling systems that provide the JOC the cumulative experience of highly trained fire controllers.

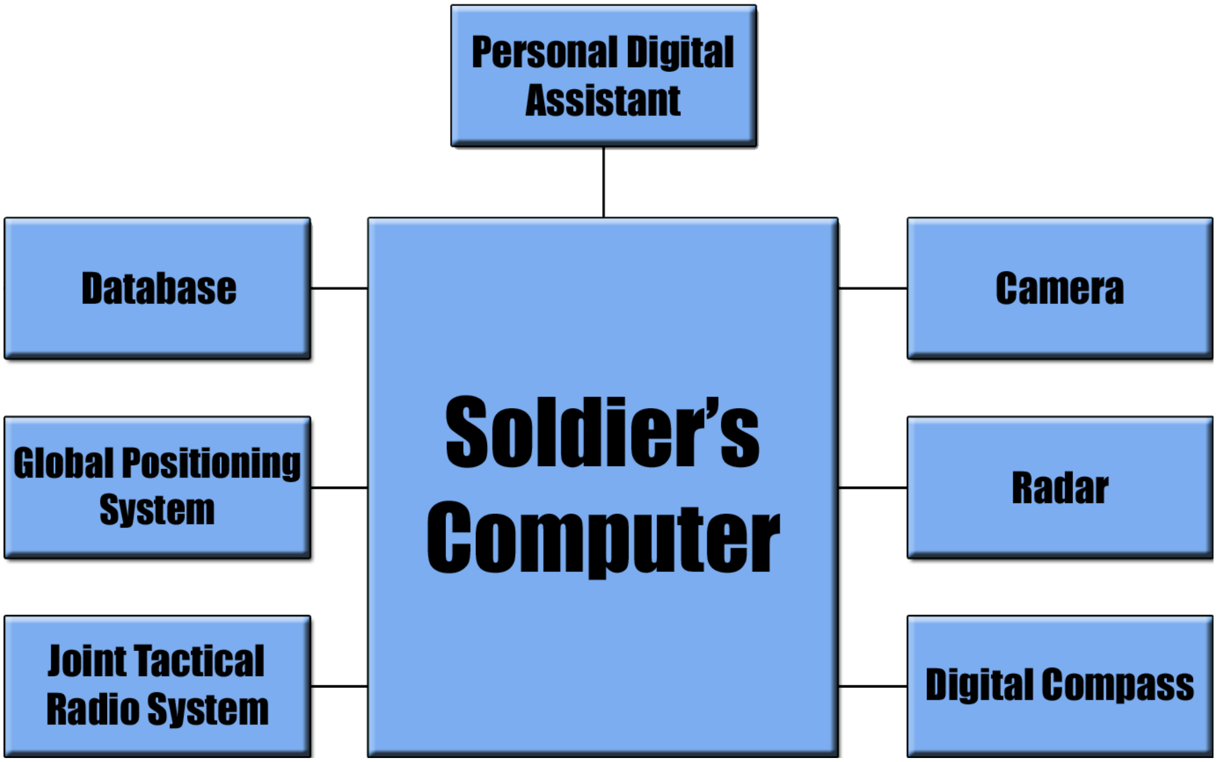

Figure 1. Proposed Indirect Fires/Close Air Support Control System Architecture

FCS postulates that each unit maintains a database called the Common Relevant Operating Picture (CROP). The CROP for a subordinate unit will be that fragment of the higher unit's CROP pertinent to that lower unit's mission. A company's CROP is a subset of the battalion CROP. The CROP is a distributed database; each organization is responsible for maintaining its own common database.

In the operational view the CROP appears as a sending and receiving node. The common databases of subordinate, peer and upper units will coordinate synchronization with one another. CROP updates are transmitted at approximately 10 kilobits per second (kbps). This implies that only small changes are made in the CROP until the units are physically reunited. A large memory storage device will be needed to carry the many intelligence items, maps, reconnaissance images and other details needed for a successful fire control/CAS mission.

Software Architecture. Interoperability among the elements of the joint force can be ensured by the System of Systems Common Operating Environment (SoSCOE). This layered software design, shown in figure 2, renders the design immune to hardware changes. Of more significance, software applications can be written once and then applied to different hardware implementations.

The following section describes an application that can be used to implement the JOC.

Model-Based Reasoning. Controlling indirect fires is an exceedingly complex task performed under extremely difficult conditions. Even with the best possible training, mistakes will be made. During the Afghanistan campaign a B-52 dropped a bomb on a Special Forces position when the controller inadvertently transmitted the unit's position instead of the enemy's location. Other "blue-on-blue" (friendly fire) incidents have occurred when coordinates were mistakenly entered into the transmitter.

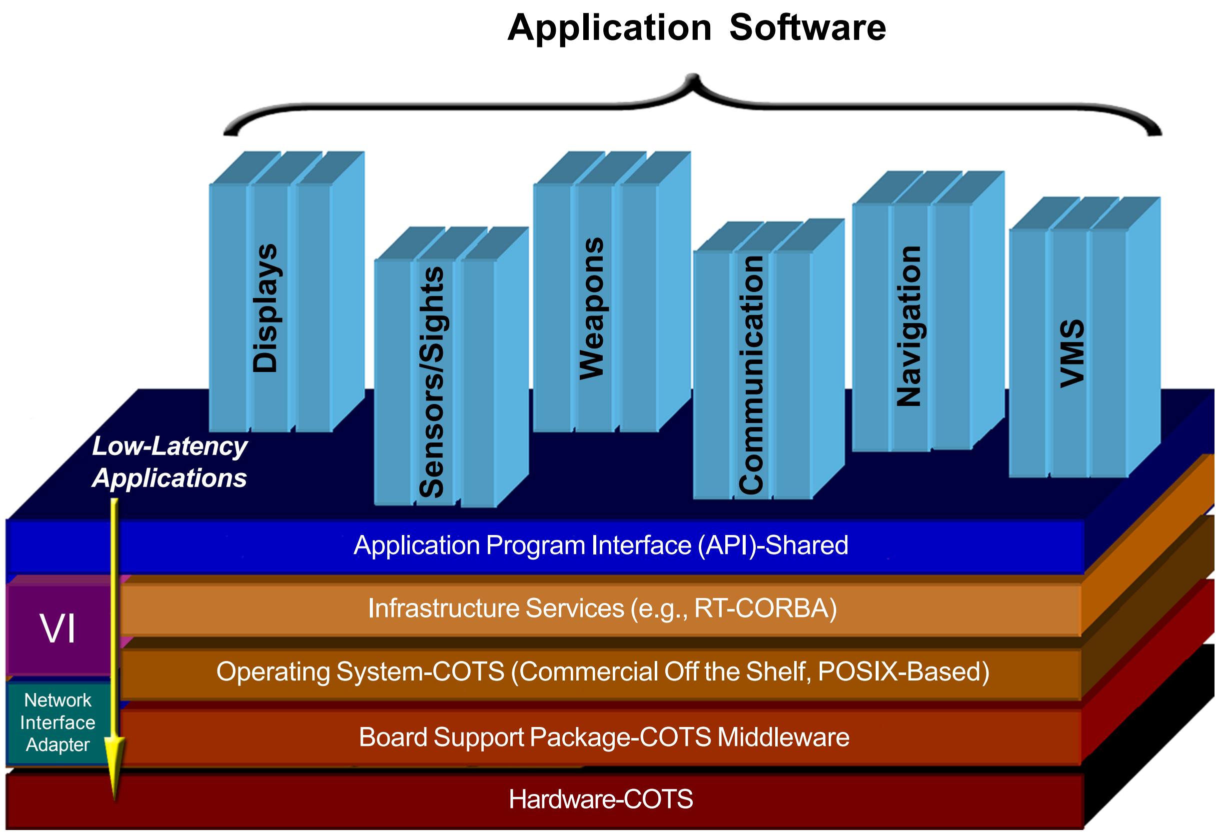

Figure 2. System of Systems Common Operating Environment

The Japanese undertake in their manufacturing a process called "poke yoka," translated usually as "fool-proofing" or perhaps "idiot-proofing."[20] Whenever an error occurs on a production line the mistake is analyzed with the intent of ensuring, usually through mechanization, that the mistake can never occur again.

The equipment used in fire control operations is not integrated and does not incorporate fail-safe measures other than the operator's training. A simple approach would link the equipment so that data automatically transfers from measuring element to transmitting element. Fail-safe rules embedded in an expert system would preclude mistakes such as targeting one's own position. Other rules would examine the database to ensure that the appropriate weapons were requested for the area, taking into account friendly force and civilian locations.

The Soldier as Internet Protocol Node

In its transformation the Army is seeking to replace weight and killing power with knowledge. Precision is the defining requirement: precision in locating the enemy, precision in placing friendly units in a position of advantage, precision in destroying the enemy.

The Tactical Internet (TI), designed to operate with fire support units and combat service support units, provides the communications for that precision. TI is an information system that provides horizontal and vertical digital information exchange at multiple echelons (from platform to platform, or from platforms up through commanders). Physically it is a network of routers and radios that utilize network protocols to disseminate situational awareness (SA) data and command and control (C2) traffic. The SA data provides position information on each friendly platform reporting on the TI as well as enemy and obstacle reports provided by friendly platforms. The C2 information can send a message to specific addresses, a group address or a multicast to multiple groups on the local net. To achieve this objective the Soldier will need four technologies: a method to communicate critical information to the indirect fire element, a method to determine his location, a method to determine the enemy's location, and the training to use the equipment to produce the desired results.

The new communications links platform is the Joint Tactical Radio System (JTRS). The current proposal would provide two waveforms to the individual Soldier: the Single Channel Ground and Airborne Radio System (SINCGARS) and the Small Unit Operation-Derivative (SUO-D).

SINCGARS operates in the low end of the very high frequency (VHF) band, 30 to 38 MegaHertz (MHz). The SINCGARS waveform can be operated without encryption for anti-jam (A/J) communication or with encryption for secure, A/J communications. SINCGARS uses a frequency-hopping algorithm to enhance security and the Joint Variable Message Format (JVMF) message set. SUO-D is a new waveform provided by JTRS. It operates in the frequency range between 20 MHz and 2.5 GHz. Depending on the range the waveform can provide between two kbps and three Megabits per second (Mbps).

Commercial communications are pointing the way to linking Soldiers into a network. Internet Protocol (IP) applied at the communications systems network layer provides a foundation for seamless end-to-end communications. The Soldier becomes an IP node through the implementation of four essential web-enabling components: IP, Extensible Markup Language (xML), Universal Resource Locator (URL) and browser-based applications.

IP version 6 (IPv6). Interfaces will be standardized through the IP. Using the IP, Soldiers can have standard addresses for accessing, just like the telephone system. This provides a common mechanism for moving data on standard networks from the Soldier anywhere in the world. IP-enabling our information systems will permit them to be connected to the Joint Armed Forces shared network, e.g., Non-Secure Internet Protocol Router Network (NIPRNet) or Secret Internet Protocol Router Network (SIPRNet). As with the telephone system, once connected the caller needs only the address (telephone number) of the party to be called. He can call from anyplace on the globe, and the connection path and media are transparent.

The current IP standard is version 4 or IPv4. This will be replaced with IPv6, which will allow the network to utilize 128 bits in its addressing (equivalent to 3.4×10^{38} nodes), enough to give every bullet in the Navy, Air Force and Army its own IP address if anyone could come up with a reason to do so.[21] Certainly, each Soldier and each vehicle would have its own IP address. IPv6 provides for multicasting, the ability to transmit the same message to multiple stations and mobile nodes. It also fully supports Encapsulating Security Protocol/IP Security Protocol (ESP/IPSec) for security.

Extensible Markup Language. Data transfers will use the xML to aid publishing of and searching through information via a standard language, just as English is the standard language for pilots. With xML as a tool the Soldier can publish data to a global data storage network. The data is stored in a "universal" format available to many systems and users. Anyone using the global data storage network and common description labels provided in xML can find any item within the database.

Universal Resource Locators. URLs and browser-based applications, when combined with xML and IP, provide users with tools to efficiently and quickly access and use applications. Adopting a URL provides a network address for any information system so it can be accessed from anywhere on the net via a directory. When applications are browser-based, users are presented with a simple and consistent way of interacting with them—just like the computer one uses at home.

Browser-based Applications. Browser-enabling an information system permits access to the application and data from the network through a wide variety of devices (e.g., handhelds) not just personal computers, keeping the system up to date with the latest revisions.

Location, Location

Once the JOC has the necessary processor, memory and communications, the location of friendly forces and hostiles must be determined.

Differential Global Positioning System. U.S. forces make widespread use of the Global Positioning System (GPS), which provides location within one to five meters of error.[22] It is surprising that its cousin, differential GPS, is not used as much. Differential GPS involves two receivers, one stationary and another mobile. Four satellites transmitting timing signals are needed to establish a position. Each timing signal has an error or delay induced by variations in the atmosphere. The stationary or reference receiver is located at a point that has been accurately surveyed. When the reference receiver and the second receiver are fairly close to each other, say within a few hundred kilometers, the signals that reach both of them will have traveled through virtually the same slice of atmosphere, and so will have virtually the same errors. The reference receiver, rather than calculating its position, uses its known position to back calculate the timing errors. It provides correction information to the other receivers which, for various reasons, are less certain of their locations. In this manner virtually all errors can be eliminated from the system, even the selective availability error that the Department of Defense (DoD) deliberately adds. Differential GPS can provide the location of a moving vehicle to within an accuracy of three or four millimeters. Such resolutions would pinpoint a friendly unit's location enough for close supporting fires.

Blue Force Tracking (BFT). In Iraq the Army deployed the Force XXI Battle Command Brigade and Below (FBCB2) system.[23] FBCB2 transmits, receives and displays friendly and enemy positions on common digital map base and satellite imagery. This information provided to the JOC and the weapon systems operators will permit the enemy to be engaged without fratricide.

Ranging Devices. CAS controllers and forward observers s use laser designators to determine distance to targets. The devices provide excellent accuracy up to five miles away if a direct line of sight can be found. Unfortunately, the laser designators are expensive and heavy, unsuitable for JOC operations.[24]

The JOC would use simple, handheld radar. Although it would be effective out to only 3,000 feet, the radar would be suitable for an enemy who has closed with a small unit with an urgent need for supporting fires but without a specialized controller. Radar has the additional benefit of being relatively unaffected by smoke and dust. It would also be light and draw relatively low power as compared to a laser designator. A magnetic compass and inclinometer are affixed to the radar. These two sensors provide direction and elevation of the target with respect to the JOC. The information is transmitted to the Soldier. This reduces the possibility of a mistake in relaying data that could cause an error in weapons impact.

Voice and Images. Fire support can be summoned using voice or data links. The advantage of data links is speed and accuracy of data transmission. However, if the data entered is incorrect, as happened during the liberation of Afghanistan, the result can be a fratricide incident.[25] Also, when the controller is under fire, data entry into the link can be problematic. Voice, on the other hand, can be more descriptive than a JVMF message. Guiding a weapons system to a target using just voice can be a long process and subject to confusion. Furthermore, when the Soldiers are in close proximity to the enemy, the need to keep voices low is paramount.[26]

In the proposed JOC design the controller also carries a camera. Transmitting an image, particularly one that is geospatially referenced, to the aircraft or artillery would significantly lower the time to locate the target. The pilot would see what the controller sees. In the case of CAS, as the pilot sees the target the probability of a kill on a single pass increases survivability. Even if the target is not present in the image, the image would reduce the area that needed searching.

The bandwidth of the SUO-D waveform, as shown in the following calculations, offers the ability with a suitable compression algorithm of passing a still picture from the Soldier to a fire support element. If the Soldier is using a camera with a resolution of 640 x 480 picture elements (pixels) with 24 bits assigned to each pixel, a single image will generate 921,600 bytes. A suitable compression algorithm, such as JPEG 2000 (50:1 compression), will reduce that to 18,432 bytes, but header information will swell the data back to 35,632 bytes. At the 3 Mbps data rate the image will transfer in approximately 0.1 second. The ability to transfer an image that quickly could have a profound effect on the ability to control indirect fires.[27]

Indirect fire elements and CAS would use images as positive target identification in high-risk areas where noncombatants are present. Appropriate selection of ammunition and fuzing options would minimize collateral damage. The images also provide an additional measure of security. If the camera is pointed at the position occupied by friendly forces the weapons operators may be able to recognize equipment.

Unmanned Aerial Vehicle and Unmanned Ground Vehicle Control. Battle space conditions, including fog, low clouds, rain, snow and obscurants (such as fog, oil, dust and smoke) affect IF/CAS targeting. These conditions degrade both electro-optical and radar targeting systems as well as laser rangefinder/designators. In addition, complex, compartmentalized terrain such as urban areas or mountainous environments limit line-of-sight distances and increase the difficulty of target detection. Air defense weapons represent an increased threat to CAS.[28] It is probable that air defense ambushes and the innovative use of passive air defense weapons (i.e., man-portable air defense system, light antiaircraft artillery) may be encountered anywhere on the battlefield. This can place both manned and unmanned aircraft at greater risk than in previous contingencies. Aviation assets represent high-value targets that an opponent exercising asymmetric tactics would attack.[29]

The Army is developing Manned and Unmanned (MUM) air maneuver teams comprising the AH-64 Apache attack helicopter and armed UAV. Each MUM team member complements and compensates for the strengths and vulnerabilities of the other.[30] One can extrapolate a similar team in which infantrymen control the UAVs and Unmanned Ground Vehicles (UGVs) to accomplish the mission—call it the Robot and Dismount (RAD) team.

At this stage of development UAVs and UGVs resemble the first tanks employed at Cambrai in November 1917. Technically impressive in some ways, lame in others, UAVs and UGVs today and the first tanks in 1917 suffered from doctrinal shortcomings that severely limited their utility. Part of this is reactionary: the cavalry didn't want to be replaced by mechanical monsters, and pilots don't want to compete with computers.[31] A lack of imagination and technological limitations also are factors in utilizing a new technology.

MUM systems using UGVs, UAVs or a combination of the two could provide synergies in operations. An armed UAV or UGV can:

- perform the dirty, dangerous business of ferreting out concealed enemy forces;
- provide precision engagement with on-board weapons or provide precise target location updates for indirect fire/beyond-line-of-sight (BLOS) weapons;
- with a variety of sensors identify and engage targets employing camouflage, cover, concealment, deception and denial (C3D2);
- minimize latency between target acquisition and target engagement; and
- perform real-time battle damage assessment.

NATO has developed five definitions of UAV control:[32]

- Level 1—Indirect receipt of secondary imagery or data;
- Level 2—Direct receipt of payload data by a controller/receiver where "direct" covers reception of the UAV payload data by the controller/receiver when it has direct line-of-sight with the UAV or a relay device which has direct line-of-sight with the UAV;
- Level 3—Level 2 interoperability and control of the UAV payload by a controller/receiver;
- Level 4—Level 3 interoperability and UAV flight control by a controller/receiver; and
- Level 5—Level 4 interoperability and the ability of the controller/receiver to launch and recover the UAV.

A similar set of definitions could be applied to UGVs.

To obtain the full effect of the MUM systems, control of the robotic vehicles must be allocated to the individual Soldier. Again, simplicity is important. A commercial program that uses a map sketched on a Personal Digital Assistant (PDA) provides an uncomplicated method of controlling the path of a robotic vehicle.

Training

A number of factors have coincided to reduce the ability of the military to conduct training, including a large reduction in the availability of artillery training ammunition and the number of training areas that allow the firing of artillery ammunition.[33] In addition, many restrictions have been placed on the firing of artillery ammunition at ranges still operating. For example, during many months of the year the potential for starting a wildfire from exploding artillery shells prohibits live fire training. The close proximity of populated civilian areas can also limit the time of day artillery can be fired due to noise restrictions. The presence of endangered wildlife and other environmental concerns surrounding the firing of various artillery munitions, such as white phosphorus, severely limits artillery live fire.[34]

Budget reductions, in addition to the limitations of live fire opportunities, have adversely affected the proficiency of the forward observer.[35] For these reasons, an alternative method for training the forward observer must be found to provide almost realistic environments to accomplish the fire missions.

One solution is to develop and use computer simulation. Many such simulations for the training of the forward observer do exist.[36] Similar programs could be developed for CAS controllers. A good stand-alone simulation for forward observer training can be written with modern technology using geographic and digital elevation data that appears realistic. The training could be provided on personal computers currently available at the unit level.

Simulation can provide initial and sustainment training for the JOC by enabling the student to practice locating targets, calling for and adjusting IF/CAS, and reporting the results of support on a simulated battlefield. An instructor would build and control battlefield scenarios while inserting uncertainty into the simulation.

Thunder Run Revisited

Artillery and CAS can play a major, active role in convoy escort and operations conducted in rugged terrain and urban areas. Precision-guided munitions, such as the forthcoming Excalibur, will have a vital role in these missions. Receiving critical information on a viable target will be a difficult problem for artillery and attack aircraft when specialized controllers are unavailable. The following scenario, based on the "Thunder Run" into Baghdad conducted by 2d Brigade Combat Team, 3d Infantry Division,[37] will demonstrate how the proposed system can resolve this problem.

A brigade is tasked with seizing an urban area that serves as the political center of power for an opposing force. The thrust is supported by a long supply line extending through contested territory. Small elements are deployed to secure key intersections.

The commander preplanned fires on overpasses where the enemy had fired down on a previous force that had entered the area. High explosive point detonating (HEPD) shells exploding 10 to 15 meters above the ground had cleared the enemy without damaging the roads. However, irregulars continue to attack the armored columns from bunkers with "technicals"—civilian vehicles, usually pickups, rigged with heavy weapons—and suicide vehicles.[38]

Images from an overhead UAV or the JOC support the column as it moves to its objective. Soldiers anywhere along the length of the column call in fire support or CAS. The element commander has veto power over the calls. Artillery is directed against the enemy as they move up to support the fight. Geospatial annotated images guide precision-guided munitions (PGMs) onto bunkers and other fortified strong points.

During the incursion one of the M1A1 Abrams tanks is disabled. The disabled tank with its crew is left behind as the column proceeds on its mission. A UAV patrols over the disabled vehicle and transmits images directly to the tank. The crew, using the JOC system, call in fire support to destroy any enemy attempting to attack the tank.

Mechanized infantry are deployed to control critical points along the supply line. At one of the positions, an infantry platoon with a mortar section, 80 Soldiers and Bradley Fighting Vehicles—but no tanks—are charged with defending a critical interchange. Under attack from multiple axes the unit commander uses images relayed from a UAV to engage enemy forces as they mass for an assault. The engagement could include IF/CAS as they are assigned priority to his element.

A refuel and rearm (R2) convoy is dispatched to provide urgent supplies to beleaguered units within hostile territory. The convoy comprises thin-skinned ammunition and fuel trucks. Before the convoy departs the commander is assigned priority of support, which changes as the column moves. The JOC identifies targets of opportunity, which are forwarded to the IF/CAS nodes. These nodes have information about the status of other nodes, the commanders' intent and the priorities of support.

The support mission is executed by acceptance. In this example, artillery initially has priority in support of the convoy. However, the commander has changed priorities, allocating the artillery to support of a hard-pressed infantry unit, so an alternate support must be used. The second priority is a UAV, but it has been disabled. The third priority is a Marine Cobra helicopter. The Marine pilot broadcasts that the Cobra will engage the target. The command chain acknowledges the action and the mission is executed.

Conclusion

The operational environment in which the military will function will be more challenging than any faced in the past. Operations will be conducted in complex topography (i.e., urban terrain) against an enemy equipped with advanced communications, sensors, weapons technology, weapons of mass destruction and special operating force and insurgent/terrorist capabilities on a battlefield where hostile forces intermingle with noncombatants.

Potential adversaries are adaptable and technologically savvy, leveraging proprietary and commercial information and technology combined with creative tactics to circumvent the technological superiority U.S. forces previously enjoyed. This danger is enhanced as criminal groups, terrorist cells and religious extremists fail to recognize the laws of war. They are willing, without hesitation, to exploit civilian populations to meet their objectives while evading detection and destruction.

The enemy's goal will be to fracture U.S. and coalition resolve by targeting selected U.S. and allied facilities, inflicting unacceptable casualties and prolonging and increasing the cost of continued hostilities. He will exert continuous pressure on vulnerable friendly forces across the operational environment, attempting to deny any sanctuary to the friendly force. Although the enemy may tactically mass to take advantage of a target of opportunity, he will most likely be satisfied to achieve an operational stalemate, waiting out U.S. and coalition resolve while preserving his military capabilities for future employment when conditions for success are more favorable.

Large, costly military operations will receive the attention of the global media. With the media's expanding access to independent information and communications systems, its impact will be virtually impossible to control, making it a potential ally to the enemy's cause. The enemy will attempt to exploit the international media through coverage of friendly setbacks to gain sympathy for his cause.

Three converging revolutions—one in information processing, one in unmanned vehicles and the third in precision munitions—will provide incredible offensive and defensive capabilities to small units and elements not usually associated with combat. The effects of these revolutions must flow down to the individual Soldier. Otherwise, the benefits of increased speed and tactical intelligence will be dissipated within the command and control structure.

The Army in many of its missions is operating in small groups, often widely dispersed. Specialized fire support personnel are not always available in these small units. The JOC concept expands the capability to control IF/CAS. Process simplification, system integration and expert systems will enable the typical Soldier to control IF/CAS in the multiple methods provided by the U.S. Army, Air Force, Marine Corps and Navy. Commanders will have more flexibility in providing inorganic weapon support without worrying about whether the unit has matching personnel skills to control and direct the support.

Endnotes

1 "Savage wars of peace" is a term used to define small wars fought between a great power and a lesser power or elements within the lesser power's territory. Formal war is often not declared, and the enemy is irregular forces, either guerillas, terrorists or a combination of the two. *The Savage Wars of Peace: Small Wars and the Rise of American Power* by Max Boot, (New York: Basic Books, 2002) and *A Savage War of Peace: Algeria 1954–1962* by Alistair Horne (New York: Viking Press, 1978).

2 Two years and considerable practice are required before an airman can become a member of an Enlisted Tactical Air Control (ETAC) team. Rupert Pengelley, "In CAS of Emergency, Contact the Universal Observer," *Jane's International Defence Review,* April 2004, online service.

3 FCS postulates that a division will operate over an area 200 kilometers x 300 kilometers; in World War II a division was considered overextended if it held an area 20 kilometers x 10 kilometers.

[4] See, for example, the ambush of elements of the 507th Maintenance Company at Nasiriya. Todd S. Purdum, *A Time of Our Choosing: America's War in Iraq* (New York: Times Books, 2003).

[5] After the fall of Baghdad the enemy forces focused his attacks on soft targets such as supply convoys while avoiding contact with combat arms teams.

[6] Richard C. Dorf and Robert H. Bishop, *Modern Control Systems* (Upper Saddle River, N.J.: Prentice Hall, 2004) and Benjamin C. Kuo and Farid Golnaraghi, *Automatic Control Systems,* (New York: John Wiley and Sons, 2004).

[7] Comments by Major General Franklin Hagenbeck, Commanding General, 10th Mountain Division, during Operation Anaconda, as reported in Pengelley, "In CAS of Emergency."

[8] David J. Morris, *Storm on the Horizon: Khafji—The Battle That Changed the Course of the Gulf War* (New York: Free Press, 2004), pp. 98–106.

[9] Calling in CAS can be extremely time consuming and often unsuccessful under combat conditions. If all friendly units cannot be located, CAS will not be employed. Pengelley, "In CAS of Emergency."

[10] Mark Hewish, "Battlefield Air Operations: Weight and Time are the Main Targets," *Jane's International Defence Review,* May 2004, on-line service.

[11] Tony Capaccio, "The Fully Deployable Air Campaign," *Air Force Magazine,* January 1994, pp. 50–54.

[12] Hewish, "Battlefield Air Operations."

[13] The 101st Airborne Division (Air Assault) has begun development of a Joint Fires Training Strategy. In this activity FOs are trained in CAS operations and ETACs are trained in Army call-for-fire procedures. Understanding one another's capabilities and limitations will improve fire support for the division. Pengelley, "In CAS of Emergency."

[14] Rebecca Grant, "The Clash About CAS," *Air Force Magazine*, January 2003, vol. 86, no. 1.

[15] William Head and Earl H. Tilford, Jr., *The Eagle in the Desert* (Westport, Conn.: Praeger Publishers, 1996).

[16] NCO involves entities linked or networked by an infrastructure and sharing information among the various components of that infrastructure. The ability to "know what is" and predict "what will be" is the major tenet behind NCO.

[17] The GIG is the globally interconnected, end-to-end set of information capabilities, associated processes and personnel for collecting, processing, storing, disseminating and managing information on demand to warfighters, policymakers and support personnel.

[18] In 1965 Moore observed that the number of transistors per square inch of integrated circuit doubled every year and predicted that this trend would continue. Later, the doubling slowed to 18 months and is expected to continue at that rate for at least the next 20 years. The number of transistors per unit area is a rough measure of processing power. "Silicon: Moore's Law," Intel Corporation website, http://www.intel.com/research/silicon/mooreslaw.htm and "Wikipedia: The Free Encyclopedia," http://en.wikipedia.org/wiki/Moore's_law.

[19] A single-platter, 20-gigabyte disk drive measures a mere 54mm x 78.5mm x 5mm and weighs 51 grams, while a two-platter, 40-gigabyte model adds only 3mm in height and 11 grams in weight. The drives can withstand operating shock of 250 times the force of earth's gravity [G] and non-operating shock of 1000G.

[20] "Lean training: Poka Yoke," LEAD Lean Advisors Inc. website, http://www.leanadvisors.com/Lean/tools/poka_yoke.cfm.

[21] There are approximately 6 billion or 10^9 people in the world. After giving one address to each person there would still be about 10^{26} (10 followed by 26 zeroes) addresses left over.

[22] "Introduction to the Global Positioning System for GIS and TRAVERSE—Chapter Six: The GPS Error Budget," CMTinc.com website, http://www.cmtinc.com/gpsbook/#chap6.

[23] An alternate view of the effectiveness of the digital system deployed in Afghanistan and Iraq is provided by David Talbot, "We Got Nothing Until They Slammed Into Us," *Technology Review*, November 2005, pp. 36–45.

[24] Hewish, "Battlefield Air Operations."

[25] Mackubin Thomas Owens, "Fratricide and Friction: Perfection in War," *National Review Online*, http://www.nationalreview.com/comment/comment-owens121101.shtml.

[26] Morris, *Storm on the Horizon,* p. 246.

[27] The proposal suggests a single image of the target rather than streaming video, which transmits images between 1 Hz and 30 Hz, or real-time video, which transmits images at rates above 30 Hz. The latter two transmissions consume more bandwidth than is available. Calculations for various digital transmission schemes are shown in Keith Jackson, *Video Demystified: A Handbook for the Digital Engineer* (Eagle Rock, Va.: LLH Technology Publishing, 1996).

[28] Major Leon E. Elsarelli, U.S. Air Force, "From Desert Storm 2025: Close Air Support in the 21st Century," Air Command and Staff College Report, AU/ACSC/086/1998-04.

[29] Major General Joseph Bergantz, Jim Delashaw, Steve MacWilli, and Don Woodbury, "Manned and Unmanned Experimentation: Enabling Effective Objective Force Operations," *Aircraft Survivability,* Joint Technical Coordinating Group on Aircraft Survivability, Fall 2002.

[30] *Ibid.*

[31] J.F.C. Fuller, *Tanks in the Great War1914–1918*, (Nashville, Tenn.: The Battery Press, 2003).

[32] NATO Standardization Agreement (STANAG) No. 4586, *Standard Interfaces of UAV Control System (UCS) for NATO UAV Interoperability*.

[33] Major Ilias Svarnas, "The Artillery Fire Direction Center Simulation," Naval Postgraduate School, Monterey, Calif., September 2003.

[34] *Ibid.*

[35] *Ibid.*

[36] Pengelley, "In CAS of Emergency."

[37] David Zucchino, *Thunder Run: The Armored Strike to Capture Baghdad* (Boston: Atlantic Monthly Press, 2004).

[38] The Iraqis chose the wrong side of asymmetrical warfare in defending Baghdad, apparently trying to duplicate the Somalis. It was reported that Saddam had distributed the movie Black Hawk Down to his commanders. Historians may ponder how Hollywood might have affected Iraqi strategy. Jon Christian Ryter, "Who's to Blame for Fallujah?" 6 April 2004, NewsWithViews.com website, http://www.newswithviews.com/Ryter/jon30.htm.

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