Interdiction:
Shaping Things to Come

A Research Paper
Presented To

Air Force ***2025***

by

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Executive Summary

Interdiction, based on the core competencies of precision employment and information dominance will still be used to shape the battlespace in 2025. The critical pieces of these core competencies—accuracy, lethality, target identification, and cycle time—will necessarily undergo great change in the next 30 years. The result of these changes will be interdiction with a different face but the same heart. Interdiction in 2025 will require affordable enhancements to current capabilities in the areas of accuracy, lethality, target detection/identification, and timeliness, allowing the war fighter to shape the battlespace in revolutionary ways.

A number of technological "leaps" will drive these required changes. Penetrating sensors and designators, coupled with microtechnology, will permit weapons to have the processing power required to "touch" targets in exactly the right spot. Variable lethality will permit the option of killing, delaying, deterring, or breaking targets. Synergistically combining these capabilities with intelligent system logic processing, improved target detection, decreased sensor-to-weapon cycle time, and air power will provide the necessary pieces to dominate the battlespace.

Among the systems required to build the interdiction system of systems in 2025 are: beyond-electromagnetic sensors; acoustic, penetrating, and variable-yield weapons; sensory netting; energy and particle weapons; and a virtual observe, orient, decide, and act (OODA) loop. From these systems, a nexus of three enabling technologies emerges. If pursued, these technologies will provide the leveraged investment necessary to revolutionize interdiction. These technologies include: nanotechnology for inertial measuring units, sensors, transmitters, processors and locomotion; nonlinear modeling and intelligent systems to support the virtual OODA loop; and expanded use of the electromagnetic spectrum for weapon guidance and remote sensing.

Chapter 1

Introduction

Air operations conducted to destroy, neutralize, or delay the enemy's military potential before it can be brought to bear effectively against friendly forces at such a distance from friendly forces that detailed integration of each air mission with fire and movement of friendly forces is not required.

—Joint Publication 1-02

In a time of drastic change it is the learners who inherit the future. The learned usually find themselves equipped to live in a world that no longer exists.

—Eric Hoffer

And all your future lies beneath your hat.

—John Oldham

Interdiction has been around as long as airplanes. From the early attempts at "delaying" the enemy in World War I (WW I) by releasing bombs from open cockpits to pre-Normandy battlefield preparation to dropping laser guided 2000-pound bombs on unsuspecting Iraqi tanks at night, the desired result has always been the same—to "destroy, neutralize, or delay the enemy's military potential." These interdiction tasks have historically been accomplished by killing the enemy and/or blowing up their equipment before they get to the fight—in essence, shaping the battlefield. This has not changed.

To be effective, the air warriors in WW I, World War II (WWII), and the Gulf War had to perform very similar tasks. The airmen had to find the target, deliver the weapons accurately, and ensure adequate lethality to accomplish the desired level of destruction. And they had to do these three things in a timely manner. This also has not changed.

The period from WW I to the end of WW II covered a little less than thirty years. From the end of WW II to the Gulf War was another 45 years. During both of these periods, the ability to accurately deliver lethal munitions on target in a timely manner grew tremendously (fig. 1-1). What will the next 30 years bring?

Photo Courtesy of Air Education and Training Command Photo Archive

Figure 1-1. View of the Past

Based on our core competencies of precision employment and information dominance, and pushed by the explosive growth and potential of technology, the face of interdiction will change, but not its heart. Interdiction in 2025 will require affordable enhancements to current capabilities in the areas of accuracy, lethality, target detection/ identification, and timeliness, allowing the war fighter to shape the battlespace in revolutionary ways. In describing these changes, this paper will define the required capabilities, describe the system components, detail a conceptual system that incorporates these components, and propose high-yield areas to investigate.

Although many discoveries could apply to battlespace shaping in other mediums, the focus of this paper will be nonnuclear land interdiction. Additionally, as we examine interdiction, a logical line of questioning is, "Why does this conceptual system only do interdiction? Why not strategic attack? What about close air support? What is unique to the interdiction mission that limits this system's application?" The answer to the final question is—absolutely nothing! As our battlespace awareness increases, the artificial lines that divide the battlespace will continue to fade. This interdiction system can be effectively employed throughout the entire spectrum of attack operations, from strategic attack to close air support.

Chapter 2

Required Capability

This chapter examines the capabilities airpower must provide for the interdiction mission of 2025. In broad terms, the required capabilities fall into two of airpower's core competencies: precision and information dominance. Precision, the ability to achieve specific desired effects, rests on the two pillars of accuracy and lethality. The second core competency—information dominance—stems from correct target detection and identification coupled with compressed sensor-to-shooter cycle time.

By 2025, hostile forces will have learned from our current capabilities and, as a result, they will adapt their systems and tactics to survive. The expanded 2025 interdiction arena, which includes conventional war, military operations other than war (MOOTW), weapons of mass destruction (WMD), counter proliferation, theater missile defense (TMD), and counterdrug operations, will be extremely challenging. For example, the target could be a small group of nonuniformed, lightly armed people walking through a jungle or through a city. Or the target could be fast, stealthy, armored vehicles, massed or dispersed. The 2025 interdiction system will engage such targets and meet those challenges.

The interdiction system in 2025 is characterized by force qualities based on the following basic tasks: detect, identify, decide, engage, and survive. The interdiction system of 2025 must excel at performing these tasks. A general sampling of the force qualities for these tasks includes but is not limited to coverage, timeliness, accuracy, availability, survivability, completeness, speed, resolution, stealth, range, optimum lethality, decision quality, and reliability.

In layman's terms, the interdiction system must do a variety of things well. First, it must achieve a complete and correct picture of the battlespace. Next, it must perform the proper action to achieve the desired results. Both of these things must be done in an adverse and countermeasured environment. The correct picture will be an accurate understanding of the location and movement of people and equipment in the designated battlespace. Additionally, coverage of a significant geographic area could be needed for major contingencies. Coverage will vary by scenario, but tens of thousands of square kilometers could be needed. The density of coverage is also critical. Sensor sample density need not be spaced to the centimeter. However, distances as close as hundreds of meters between samples might permit important features of the battlespace to be missed. Similarly, because different sensors detect different things, multispectral and/or multiple sensor types are needed. Finally, it is critical that the enemy system be modeled with sufficient fidelity to enable accurate prediction of hostile actions and reactions.

The enemy is a living, breathing organism that reacts to our actions. Col John Boyd, fighter pilot and renowned thinker, envisioned a way to conduct war based on OODA quicker than that enemy.[1] A key to employing this OODA loop effectively is to better anticipate the effect of an "act" on the enemy—and precisely placed ordnance enhances that ability to anticipate. Decreased cycle time, coupled with precision, permits the warrior to "get inside" the adversary's OODA loop and dictate the course of the battle. Col John Warden, another airpower strategist, echoed this sentiment when he stated, "They [precision weapons] change the nature of war from one of probability to one of certainty."[2] To Colonels Boyd and Warden, the term "precision" meant more than just being accurate. Precision in this context meant being able to use a weapon in such a manner as to cause a predicted, desired effect for the purpose of advantageously shaping the battlefield. Clearly, interdiction in the future will require even more accurate and lethal munitions delivered in a timely manner.

The defense budget today is not growing. There is no reason to believe this will change by 2025. With an aging population and possible bankruptcy of Social Security, there will be great pressure to spend dollars on social services rather than military equipment. Therefore, any money spent on airpower will have to be evaluated on a strict cost/benefit basis. While this is not a required capability *per se*, affordability in 2025 will be a driving factor.[3]

Mission Task Requirements

Precision and information dominance—accuracy, lethality, detection, and cycle time—will allow airpower to shape the battlespace. Rapid advances in technology push us to improve our systems. While not disregarding such advances, we must seek innovative capabilities and operating concepts which will pull technology forward. We must identify key requirements which, if met, will provide us the tools to achieve national security objectives in 2025. What must airpower in 2025 do to delay, disrupt, destroy, and divert hostile personnel, materiel (vehicles, weapons, supplies), and communications? The required capabilities in precision and information dominance must accomplish the following tasks:

Delay Personnel and Materiel: To stop people from moving, our system must be able to incapacitate personnel, destroy/incapacitate their vehicles, obstruct/make unusable the routes of travel, or convince them they don't want to make the trip.

Disrupt Personnel and Materiel: Sow confusion (C^4I interference, psyops), force the enemy to take actions of higher priority than moving.

Destroy Personnel and Materiel: Lethal attack to attrit unit to point of inability to function productively, destroy organizational integrity, and sufficiently damage critical materiel or render it useless.

Divert Personnel and Materiel: Induce them to move in a direction beneficial to us or give them a problem to solve which takes them from their intended course of action. Create a need for the materiel somewhere else, or induce the logistic system to send the materiel to the wrong place.

The system or systems required to carry out these interdiction tasks in 2025 will be comprised of personnel, organizations, delivery platforms, weapons, sensors, command and control systems, communications infrastructure, and support. In time of war or conflict, these resources must form a system able to destroy, disrupt, delay, or divert modes of transportation such as vehicles, roads, railroads, bridges, communication links, and even people. The system must operate in all environments: urban, jungle, desert, day, night, and in adverse weather. It also must be supported with timely intelligence and prioritization. The system will have to survive against a constantly evolving threat.

To perform these tasks adequately, the future interdictor will demand a broad range of options. The "emerging means of denial"[4] range from sticky foam and sonic guns to lasers and high-powered microwaves, but those are evolutionary advancements. This paper focuses on the revolutionary requirements—improvements in accuracy, lethality, target detection, and cycle time—which will lead us to the capabilities for interdiction in 2025.

Accuracy

Tomorrow's weapons, such as the joint direct attack munitions (JDAM) and the joint standoff weapon (JSOW), will autonomously guide to within 10 meters, whether day or night, and in adverse weather. The weapons of 2025 will need to be significantly more accurate.

How much more accurate? "A reporter for the *New Republic* was in Baghdad the night of the first [Gulf War] air strike and the following morning watched smoke pour out of the Iraqi defense ministry. He was amazed that the hospital next to it was untouched as were the homes surrounding the ministry."[5] With the ability to surgically remove a building from a city, what benefit is even greater accuracy? In Vietnam, news broadcasts brought the war to every American household by showing the death, destruction, and human suffering of civilians and soldiers alike. In the Gulf War, news broadcasts were live as the fighting occurred. Mass media continues to bring wars closer to the public. Ravages of war have always worked against public opinion. By increasing accuracy, airpower will continue to decrease collateral damage, helping prevent the loss of public support.

Today, we can skillfully remove a building within a city. By 2025, we may need the ability to strike specific offices, computer rooms, or command posts deep in the bowels of buildings without destroying the entire building. Enemy forces will no longer be able to hide among the civilian populace, endangering innocent lives. During the Gulf War, airpower inadvertently destroyed a fallout shelter for civilians which was collocated with a command post. The precision munitions/sensor combination of 2025 will need the ability to see inside the structure, penetrate various floors and walls, and detonate in the desired location. The result? One destroyed command post with few or no civilian casualties in the fallout shelter. Similarly, bridges could be dropped with a single bomb if it could exactly hit the main spar. The bomb yield could be smaller and collateral damage limited. This level of precision requires accuracy measured in centimeters rather than meters.

Lethality

Improved accuracy will help us obtain greater lethality. But what is lethality? Lt Col Edward Schantz defined "the essence of combat lethality" as "[t]he ability to rapidly deploy an overwhelming force, target precisely, inflict maximum destruction with the minimum of assets, attack a wide range of targets nearly simultaneously to paralyze the enemy, and to suffer and inflict the minimum number of casualties."[6] Another source took a slightly different view, describing lethality in two degrees, hard kill and mission kill.[7] A hard kill completely destroys the intended target along with any nearby people. In contrast, a mission kill disables the equipment permanently or destroys supplies while sparing human life in the vicinity. Additionally, future interdiction in some instances must have the ability to prevent enemy mission accomplishment while preserving life and infrastructure.

Fulfilling this requirement for variable lethality will permit airpower to effectively interdict in nontraditional arenas such as MOOTW, WMD counterproliferation, and TMD. The targets in these areas demand a wide range of lethality. Furthermore, in both these and conventional missions, we may need to preserve infrastructure (keep bridges standing, railroads functioning, etc.) yet still delay, disrupt, divert, or destroy. Limiting collateral damage is a driving concern in executing military operations today, and this trend will only increase.

Target Detection and Identification

Rapid target detection, identification, and endgame decision making to optimize weapons effects will be equally important. Knowledge of seemingly insignificant characteristics of the battlespace will be necessary. How else will the war fighter be able to predict, with an acceptable degree of certainty, the effect of his actions on the battle? This requirement demands sensors capable of operating across and outside the electromagnetic spectrum. Processing capability at the scene will be necessary to screen out unwanted data and identify items of interest as well as discern friend from foe and neutral bystanders.

Cycle Time

Systems which gather prescreened data should be capable of rapid information collection, knowledge enhancement, picture-building for the operator, and efficient dissemination of targeting information. With cycle times reduced to minutes or seconds, the only way to improve exploitation of the adversary's OODA loop is to accurately predict his movement in relationship to the battlespace. But the battlespace is, by definition, chaotic, requiring nonlinear modeling. The side that is able to employ vast computational power, with algorithms capable of simulating the chaotic nature of events as they unfold, will achieve information dominance.

Emphasis on accuracy, lethality, target detection, and cycle time as viewed by the Joint Chiefs of Staff[8] and senior Air Force leadership is at an all-time high.[9] Current trends in these areas show great promise. The required capabilities for interdiction in the 2025 battlespace demand revolutionary technologies.

Notes

[1] Maj David S. Fadok, John Boyd and John Warden, *Air Power's Quest for Strategic Paralysis*, Thesis for School of Advance Airpower Studies, (Maxwell AFB, Ala: Air University Press, February 1995), 13-21.

[2] John A. Warden III, "Air Theory for the Twenty-first Century," in Dr Karl P. Magyar et al., *Challenge and Response, Anticipating US Military Security Concerns* (Maxwell AFB, Ala: Air University Press, August 1994), 327.

[3] USAF Scientific Advisory Board, *New World Vistas: Air and Space Power for the 21st Century*, summary volume (Washington, D.C.: USAF Scientific Advisory Board, 15 December 1995), 5.

[4] Frederick R. Strain, "The New Joint Warfare," *Joint Forces Quarterly*, Autumn 1993, 21.

[5] Lt Col Thomas P. Mahoney, et al., "Vulnerability Analysis of the United States," Air University Library Doc M-U 43122 M2161v (Maxwell AFB, Ala.: Air Command and Staff College, 1995), 21.

[6] Lt Col Edward T. Schantz, "Combat Lethality: A Formula," Air University Library Doc M-U 43117 S229c (Maxwell AFB, Ala.: Air War College, 1994), 19.

[7] Report of US Army Strategic Defense Command, "Theater Missile Defense Lethality Sensitivity Assessments" (Huntsville, Ala., July 1993), 1-5.

[8] Adm William A. Owens, "Emerging System of Systems," *Military Review*, May-June 1995, 15-19.

[9] Department of the Air Force, *USAF Executive Guidance*, January 1996.

Chapter 3

System Description

A description of required systems will help the reader envision the technologies to be developed. This section will focus on systems for accuracy, lethality, target detection/identification, and cycle time.

Accuracy

Airpower stewards of 2025 should focus on three technologies--they are laser modulation, molecular recognition, and microsensors--to improve weapon accuracy.

Laser modulation will offer two advantages. The first advantage is the ability to penetrate a structure in a nondestructive inspection and the second is the ability to designate an exact point inside the structure, thereby guiding a penetrating munition to a precise detonation point within that structure. Laser devices generate a coherent beam by using a light source to excite atoms of a crystal, liquid, or gas medium. As the light is agitated in the crystal, liquid, or gas medium, it is reflected by mirrors. The reflected light agitates more atoms, generating more light of the same wavelength. Eventually, the light will build to such an intensity that it will overcome the reflectivity of one mirror and spill out of the laser device in a beam of coherent light. The crystal, liquid, or gas used for the lazing medium will determine the frequency and wavelength of the laser beam. Currently, there is a laser device that can modulate its frequency. It is called a "dye laser." The "tuning range can . . .be extended into the ultraviolet at the shorter end and into the infrared at the longer-wavelength end"[1] (fig. 3-1).

The energy generated in the light frequency range between microwave and ultraviolet offers only a slight amount of penetration capability. More simply, energy in the light frequency will reflect off the outside or external part of the structure. Energy in the microwave region can penetrate some materials, but will reflect off others. As the frequency or wavelength of a lazing beam changes throughout the spectrum, its ability to penetrate moisture, smoke, haze, or even solid objects, improves. This is similar to using an X-ray machine

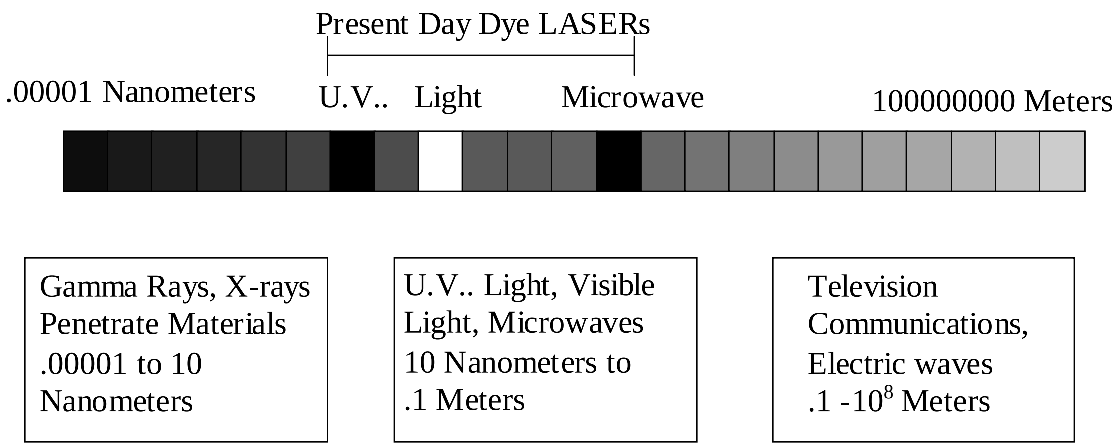

Figure 3-1. Present Day Dye Lasers

to see inside a person’s body. “The power of X-rays for penetrating matter increases as the wavelength decreases.”[2] By modulating the frequency throughout the entire electromagnetic spectrum, the device could control the frequency to penetrate or to reflect off of the various materials comprising the structure. From a database of material properties, a computer would analyze the different wavelengths based on parameters such as intensity of reflected energy, lack of reflected energy, or a shift in phase of the wavelength. Using this analysis, the computer would build a three- dimensional image of the structure and display it to the weapon operator. For example, a laser modulating weapon could examine a structure like a bridge and show the weapon operator a three-dimensional image of the internal skeleton of the structure. This would allow the weapon operator to locate the main spar and guide a weapon to an exact point inside the structure, thereby dropping the bridge with an explosive power the size of a stick of dynamite (fig. 3-2).

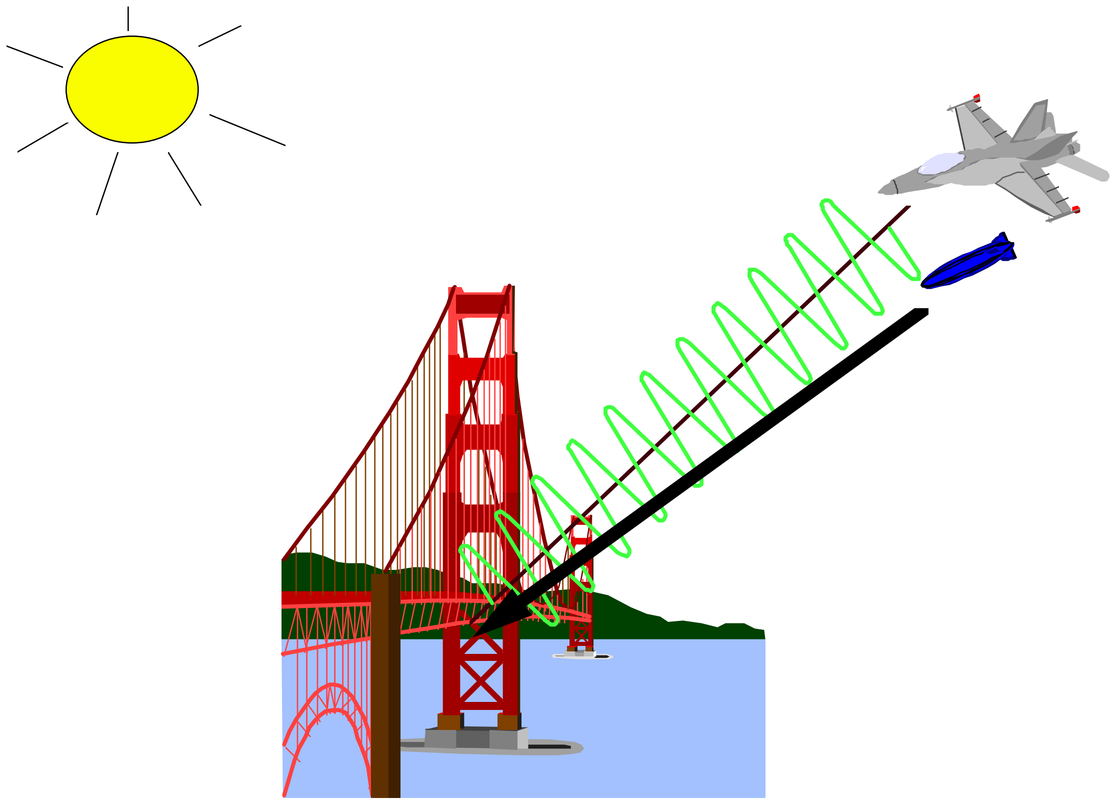

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Figure 3-2. Laser Modulating Weapon

Lazing a target may be impractical--a more autonomous system might be needed to attack a target. Some view autonomous weapons as the next challenge in improving weapons. One visionary research paper from the Army Command and General Staff College stated, "Brilliant munitions, currently in the notional [conceptual] state, will combine the autonomous operation of smart munitions with enhanced navigation and targeting classification and identification capabilities."[3] Classification and identification will be discussed later; this section will focus on autonomy. The heart for these weapons is the inertial navigation unit (INU). Today, INU errors grow by rate of time squared.[4] That is to say, inaccuracy increases at an exponential rate after initial alignment. To maintain an accurate INU, the system can be updated in-flight by different systems such as the global positioning system or terrain-imaging systems. Updating the INU provides another vulnerability to the system. Future autonomy will come in making the INU more accurate. Historically, the inertial measuring system in the INU was a spinning mass gyro which evolved to a laser gyro.

The INU of the year 2025 could be a nuclear gyro. Utilizing radioactive *molecules*, the INU will measure the smallest of changes. Orientation and acceleration will be accomplished by multiple buckeyballs

(Buckminster Fullereen molecules) containing radioactive, specially shaped nanoparticles.[5] The INU will never drift to an inaccurate state, and updating will be unnecessary. This will decrease vulnerability and provide pinpoint accuracy.

Autonomy is a great asset for stationary targets, but defining the end-game coordinates of a moving target significantly increases the level of difficulty. One approach supposes a datalink from the target to the weapon. A self-contained datalink module will attach itself to a target and transmit information to the weapon. The envisioned device will be miniature. It will have the ability to sense the composition of the target and to fuse with the target, so it cannot be removed. After fusing, the sensors will begin transmitting data, such as direction, speed, composition of material, armament, personnel on board, vulnerabilities, and other useful information to a weapon sensor. The device will transmit the information to a central computer. The computer will analyze it and other information transmitted from other targets, display a three-dimensional picture, and prioritize targets for commanders to analyze. After the commander decides which targets to attack, the computer will determine the most vulnerable point and the size of yield, and will guide the weapon to the exact point of vulnerability within the target. Improvements in miniaturization of power sources, sensors, and computers will be required.

Lethality

The word "lethal" connotes destructive power "capable of causing death."[6] In the spirit of reducing collateral damage and attaining specifically desired affects, weapons in the year 2025 will vary through a spectrum of lethality--from total destruction to target destruction without death to merely delaying or disrupting target function.

> America's national science laboratories are among those who recognize this reality [varying lethality] and are currently theorizing, developing, and testing these next generations of weapons, thereby transcending the precision guided munitions (PGM) used in the gulf war. Nonlethal technologies are the only way to fully exploit telecommunications [as well as other targets], and depending on campaign objectives, they may be cheaper, more effective, and less destructive.[7]

Regardless of the level of lethality, weapons in the year 2025 will require technological advances in target penetrability and variable yield.

Weapons will have differing penetrability characteristics in 2025. This section will explore acoustic devices that prepare targets for kinetic energy weapons to penetrate; energy or particle beam weapons that penetrate structures directly; and a revolutionary concept, weapons that bore into structures.

Most weapons today use kinetic energy to penetrate a target. It could be costly in redesign efforts and arsenal replacement to design harder, higher-velocity weapons. A more likely scenario for kinetic weapons in the next 30 years is to use the same weapons as today but prepare the target for penetration. In other words, soften the target prior to bombing it. Materials are collections of bonded particles. A device that could break down those bonds would enable kinetic energy weapons to penetrate more easily. One way to weaken these bonds is to generate a resonating frequency in the structure. A sound-producing device imbedded in or attached to a target could send sound waves throughout the structure. A computer in the device would analyze the structure and adjust intensity and frequency until the structure resonates. "The amplitude of forced oscillations becomes exceptionally large whenever the driving frequency is near a natural frequency (resonating frequency) of the vibrating body."[8] These oscillations would weaken the material in the structure, thus allowing kinetic energy weapons to penetrate more easily. Although power requirements may be substantial, several of these devices working together would be able to add to the output without causing an increase in power demands per device.

Energy or particle beam weapons penetrate by translating through materials as described above. If enough energy were added, the beam could be a destructive force itself, like a laser scalpel used in surgeries today. Limited power sources and collateral damage would restrict the use of this weapon. However, several distinct energy or particle beam weapons focusing on the same point could individually penetrate structures without harm and cause internal damage at the designated point (fig. 3-3).

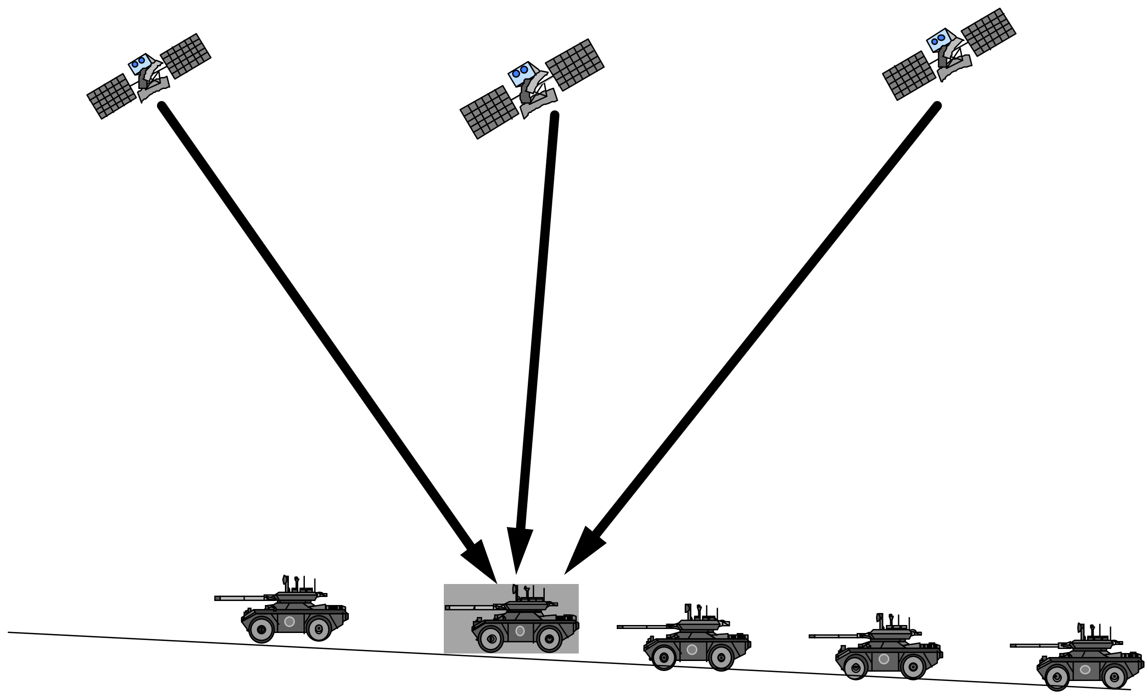

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Figure 3-3. Multibeam Attack System

These weapons could be self-contained, in orbit around the earth, and networked to a control facility either in orbit or on the ground. There are three advantages: (1) They would not individually do anymore harm to the environment than microwave stations do today; (2) the system would be difficult to kill; and (3) the individual energy or particle beam systems could easily be disguised as communication satellites. This system would require a lens with zero defects to provide very accurate aiming and limit beam attenuation. Toward solving this, Dick Siegel, a scientist at the Renssalear Polytechnic Institute, has developed a way to manipulate matter on an atomic level.[9] He would essentially build the lensing medium atom by atom. Such homogeneous materials would provide precise focusing, enabling the energy or particle beams to converge precisely, providing maximum energy at a given point.

Penetration can also be achieved by boring to the desired point. Too often we envision weapons that do all their work in a split second of time, explode, and are gone. But a weapon that could bore through any material would not have to work quickly; nor would it have to explode. This concept envisions a weapon that would work like a furniture worm. These worms bore through furniture, weakening it to the point of collapse. A bore weapon would ingest the material as it bored. The ingested material would be broken down by chemicals and enzymes. Useful molecules could be used for energy and the rest discarded. It would be very small, and many of them could infest a target. They could be linked to a central control system so as to work in unison and reach the most vulnerable spot quickly; or they could be disabled by the touch of a button if the enemy conceded to demands. Technological advances in computer miniaturization and chemical decomposition would be paramount.

If a weapon can accurately target inside a structure and penetrate to that point, then the final step is to apply the appropriate force to attain the desired effect. Energy or particle beam weapons of the year 2025 will adjust their yields by adjusting power output. Explosive weapons, however, cannot as yet adjust their explosive yield—it is a fixed parameter based on the explosive fuel in the bomb. The advantage of adjusting the yield lies in providing the most possible flexibility to the tip of the sword. An airplane, for example, with an adjustable yield weapon could be diverted from destroying a bridge, which might take a 100-pound yield, to destroying a communications room, which might take a 10-pound yield. This example shrinks the OODA loop, minimizes collateral damage, and provides the most flexibility to the war fighters. This section will examine two concepts for adjusting the yield on a weapon: metamorphic material and beam activation of materials.

Explosive weapons today use chemical compositions that, when ignited, burn at a rate and pressure inherent in the type of materials used.

> All chemical reactions are accompanied either by an absorption or evolution of energy, which manifests itself as heat. It is possible to determine this amount of heat and thus the temperature and product composition from the very basic principles. Spectroscopic data and statistical calculations permit one to determine the internal energy of a substance. The internal energy of a given substance is found to be dependent upon its temperature, pressure and state and is independent of the means by which the state was attained.[10]

Therefore, by being able to change the material composition of the weapon, one could instantaneously adjust the yield of the weapon. The concept for a metamorphic material is to develop a substance that could change its molecular structure. An electrical charge of varying voltages could be the catalyst for changing the composition of the material. A charge would cause one chemical in the explosive solution of the bomb to alter its molecular bonds, thus changing into a different solution and generating a different yield. A charge of a different voltage would make a different explosive solution with a different yield.

The concept of beam activation is similar to the metamorphosing materials described above; however, in this instance, the ordnance penetrates to the exact point required but does not detonate. A beam of energy is then applied to the ordnance from an airborne or spaceborne platform to trigger ignition. The type of energy beam will determine the yield of the explosion. For example, a microwave beam would activate chemicals in the solution different from those of an X-ray beam. Activation of different chemicals in the explosive solution would realize different yields.

Target Detection and Identification

> *There is radiance and glory in the darkness, could we but see; and to see we have only to look. . . .I beseech you to look.*
>
> **—Fra Giovanni**[11]

> *The trouble with people is not that they don't know but that they know so much that ain't so.*
>
> **—Josh Billings**[12]

Historically, target detection and identification have been sequential and loosely associated processes. Targets were detected by various means (visual, radar, infrared), located, visually identified, and finally engaged. Initially, our ability to engage a target was limited because of our inability to detect and locate targets. Increasingly, however, our ability to detect, locate, and engage has greatly outpaced our ability to identify. All of the long-range detection and engagement systems in the world are worth nothing if we cannot correctly and confidently identify the targets. As we move into the future, the speed, and consequently the ranges, at which we will need to engage will increase significantly. Furthermore, the targets and target environments of 2025 will provide much greater challenges. We will be required to detect weapons of mass destruction at long ranges. We will need to operate in urban environments. In order to successfully meet these challenges, future systems will precisely detect, locate, identify, and "know" how best to attack the enemy. This "knowing" will use a greatly expanded range of brilliant sensors, mounted on a wide variety of platforms and networked together to fuse all of the information into widely-available target knowledge.

We detect most ground targets by using the electromagnetic spectrum, either optically (using the visual or infrared spectrum) or electronically (by either radar reflection or passive emission detection). The likely proliferation of stealthing and camouflaging techniques will reduce either the effectiveness of current detection systems or our confidence in those systems. Since stealthing is usually only effective in specifically targeted regions of the electromagnetic spectrum, we must expand the range of the spectrum our systems use for target detection.

Currently, lasers are used almost exclusively as designation systems to guide munitions. By 2025, advances in laser technology will permit reflected laser energy to be processed not only to determine target location and classification, but also to build a picture of the target for positive identification purposes. Furthermore, by using laser technology identified previously in the accuracy section, these sensors will be able to look beyond the surface and into the heart of a target. This will provide additional data for target identification and decoy rejection—stealthing and camouflage will be rendered useless.

Sensors have inherent limitations associated with their operating frequencies. For example, visual systems have good resolution but cannot see through weather or in the dark; infrared systems can see in the dark but are limited by weather; millimeter wave radar works in bad weather and darkness but has poor resolution.[13] Multispectral imaging, capturing images of a given target, by using different regions of the electromagnetic spectrum and combining those images, can overcome the limitations associated with any particular region of the electromagnetic spectrum. Furthermore, not only are natural limitations overcome, but camouflage as well. A tank that is covered with branches may look like a bush, but it still has the thermal footprint of a tank. While it would be possible to disguise the tank further with thermal camouflage, it would still have the radar signature of a tank. For every camouflage short of actually building another tank, some region of the electromagnetic spectrum will reveal the camouflage.

By 2025, multilayered semiconductors and new polymeric materials will be designed and processed at the atomic level.[14] "These new materials will make possible sensors with high sensitivity across the entire electromagnetic spectrum, data transmission links with greater than 200 gigabits per second, parallel processing of data at breathtaking speeds, three dimensional data storage with almost instantaneous access. . . ."[15] Not only will these new materials "see" more; they will be able to compile multiple images much faster.

Multispectral imaging will give way to hyperspectral and ultraspectral imaging. There will be fewer and fewer places to effectively hide (fig. 3-4).

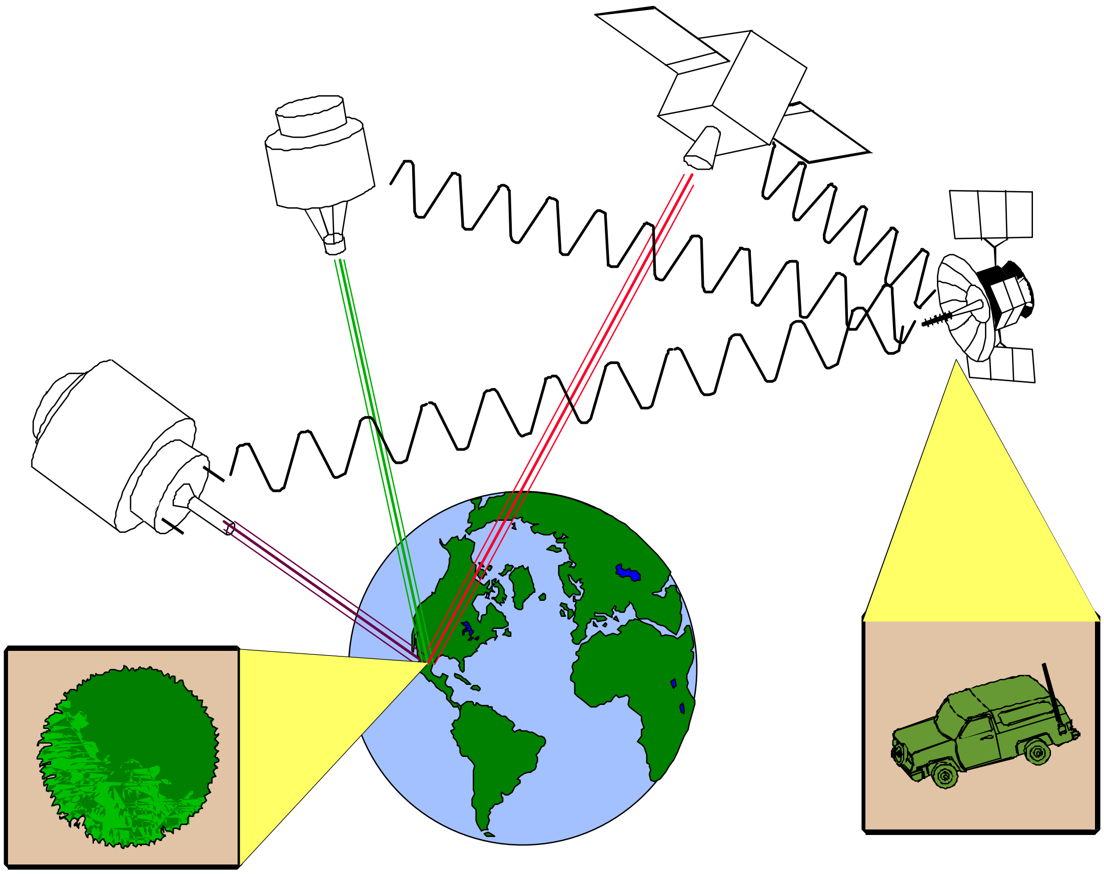

Figure from Corel DRAW!© 1992 with courtesy from Corel Corporation

Figure 3-4. Multispectral Imaging

Furthermore, sensors in 2025 will not only use more of the electromagnetic spectrum; they will move detection outside of the electromagnetic realm entirely. Scientists are developing intelligent materials that will be able to bond with objects and distinguish material characteristics of that object. Ultra thin layers, 200 to 300 microns thick, of piezoelectric polymers--like polyvinylidene fluoride (PVDF) in particular--are very sensitive to texture, temperature, and shape.[16] Sensors using these materials will be able to “taste” and “feel” targets. Furthermore, chemists are working on developing spectrometers that are the size of handheld calculators.[17] These battlefield sensors will be able to sense the environment by looking for proximate target indications like exhaust fumes while miniature acoustic sensors will be “listening” for targets. These systems would be able to “smell” and “hear” targets!

Evolutionary improvements in computational power and artificial intelligence applied to all sensor systems will lead to revolutionary improvements in performance. These systems will become “brilliant” sensors. They will be able to perform in-depth analyses of all available data and compare the results against a vast library of cataloged threat systems and friendly systems. Having analyzed the data to such a level, the sensors will be able to provide information not only on target location and identification but also on target vulnerabilities. This will permit the tailoring of force to precisely affect the target.

To enhance their utility, these sensor systems will be located on an almost infinite variety of platforms in space, in the atmosphere, and on the surface. Any form of aviation platform will be able to support a sensor suit covering the entire range of detection capabilities. Surface sensors can be either fixed or deployable. Fixed sites will approximate something like the distant early warning (DEW) line of old, while increased processing capability will reduce the size and cost of such installations. Reductions in size and power requirements will permit sensor deployment on multiple small satellites, clustered together on large satellites, or on a space station.

The area that shows the most promise for revolutionary advances in sensor technology is nanotechnology. Miniature electronic and mechanical machines can be combined and manufactured through use of the lithography techniques currently found in computer chip production. These devices, called microelectromechanical systems (MEMS), are sized on the order of hundreds of microns.[18] Advances in computers will also provide powerful processing capacity to a single integrated chip.[19] Similarly, advances in memory devices will permit a trillion bits of information to be stored on a single chip.[20] Combining this powerful computing capability with the MEMS devices will allow us to deploy the “taste,” “smell,” “feel,” and “hear” sensors directly to the battlefield as a “swarm” of “miniature unattended ground sensors” (MUGS). The MUGS could be air-dropped in the neighborhood of a supply chokepoint and become a remote sentry reporting on enemy activity. As enemy equipment approaches, the MUGS detect the equipment, identify the equipment and its contents, and report the information.

Finally, massive intelligent networking of all sensor systems will permit the widest possible dissemination of target knowledge (fig. 3-5).

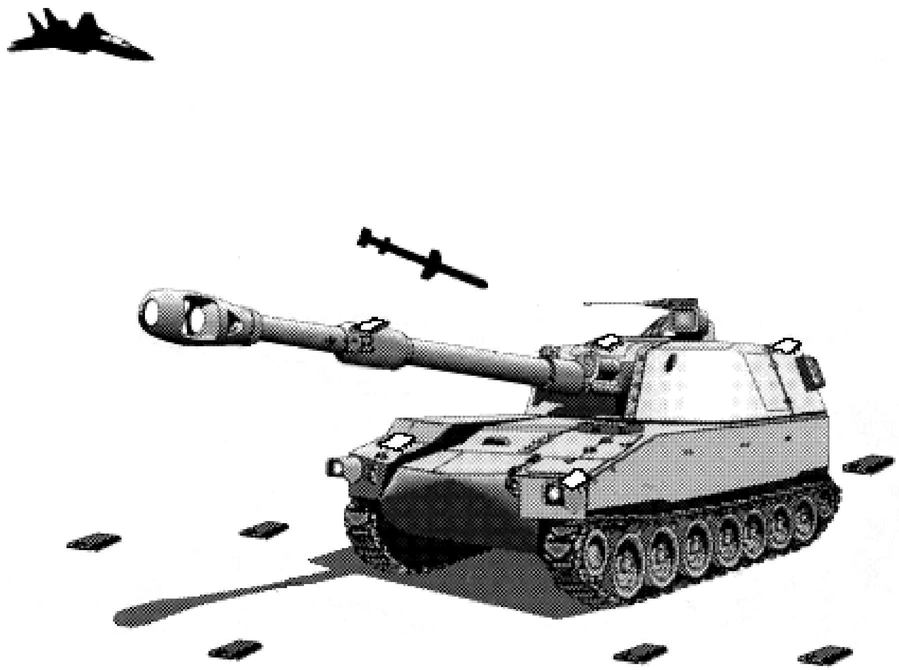

Figure from Corel DRAW!© 1992 with courtesy from Corel Corporation

Figure 3-5. Miniature Unattended Ground Sensors (MUGS)

As any individual sensor detects a target, it not only turns its full analysis capability on that target; it also identifies that target to other sensors for analysis of different modalities. All of the sensors will report their findings to intelligence networks for further analysis and possible targeting. As weapon systems are employed against these targets, the sensors will help guide munitions and optimize the effects of those munitions, as well as report munitions effects providing combat assessment. The MUGS, however, will require revolutionary advances in power and communications technologies to be able to communicate beyond their immediate environment. Short of solving these long-range communication problems, it would be possible to make the MUGS “smart” reflectors. Having locally determined the nature of a target, the MUGS would alter their state so that an energy beam reflected off them would contain meaningful target information. Passing aircraft, satellites, or other systems would be able to poll the MUGS by scanning them in passing.

Regardless of whether the MUGS are delivered by a transatmospheric vehicle, an unmanned aerial vehicle (UAV), or the Good Humor man, they will require insertion on the battlefield. While it is impossible to know at this point precise dimensions or capabilities of the MUGS, some rough calculations will give us an idea of coverage we can expect. Given that the MEMS that are currently being developed have dimensions on the order of hundreds of microns, it is not unreasonable to assume that a MUGS of 2025 with a complete suite of communications and power capabilities, camouflage, and either motive or adhesive systems would be one centimeter square by one millimeter thick. A generic delivery canister of one cubic meter capacity would hold 10,000,000 sensors. If these sensors can reliably detect targets and communicate with each other at a distance of one meter, this one container could distribute enough sensors to cover an area approximately three kilometers on a side. If the range of the MUGS is increased to 10 meters, the area is 30 kilometers on a side or 900 square kilometers.

The MUGS would be ideal for detecting weapons of mass destruction and operating in urban environments. Properly configured, MUGS will be able to detect smaller evidence of WMD, more precisely locate the WMD, report WMD movement and determine the status of the environment after an attack to destroy the WMD. MUGS placed throughout an urban environment will permit more accurate tracking of targets in that environment. MUGS programmed to detect language, cultural, and equipment differences, placed in a building in which terrorists are holding hostages, would be able to determine the number, location, and status of both terrorists and hostages. Rescue attempts would be more effective, with greater likelihood of success and fewer friendly casualties. Substitute enemy soldiers in a city and similar results can be anticipated.

Cycle Time

Cycle time, within the context of targeting for interdiction, has historically followed a cycle of "detect, decide, and destroy."[21] Although the Air Force has chosen to embrace a newer version of the decision-making process in Boyd's previously mentioned OODA loop, the process still requires events to occur before new data can be input as the observe portion of the cycle. Increasing the tempo of operations by reducing cycle times makes the employed force appear larger to the enemy. The goal of the commander is to repeat the cycle as rapidly as possible to minimize losses and maximize effect.

To maximize the effects of weapon systems in 2025, the ability to predict possible courses of action for commanders will be required. The ability to model the battlespace and explore options before actually executing them will allow analysis to determine best effects for least cost. Consider a military forecasting system capable of predicting enemy actions from twelve to twenty-four hours in advance and offering courses of action for evaluation. Using chess as an analogy, the commander will be able to predict the outcome of his third move, knowing the result of the second, while the first is taking place. Such a system, perhaps using a 3-D holographic battlefield display[22] or a battlespace awareness holosphere,[23] would allow commanders to plan interdiction sorties against centers of gravity for the upcoming enemy operation (fig. 3-6). In the holographic interface system, the battlespace is projected in a three-dimensional format so all aspects of the battle can be interpreted by the commander.

Picture Courtesy of Air Force Institute of Technology

Figure 3-6. Holographic Interface

To get additional information on a particular area or target, the commander zooms in or simply touches the object. Full details are then immediately available. If full details are not present, the system interprets the “touch” as a request; additional sensor information is then sought. The holographic system would incorporate imagery, terrain information, air defense information, knowledge of the opponent’s tactics, treaty implications, and all sensor data from the target detection/identification network. The database for the system, pervasive and distributed, draws from many sources around the world. Some possible inputs to the database include Central Intelligence Agency data, Department of State analyses of governments and engineering data on the opponents system. The holographic system will have call-up panels for other C^4I tasks. For example, to establish a link with a commander at another center, the operator will touch the appropriate unit’s symbol and a video conference link is established with the other commander. The system would project the battlespace at the level of detail requested by the commander, and providing a real-time view of enemy and friendly forces. The ability to simulate attacks on various enemy targets, inflict damage to friendly forces, and view the results are integral parts of a battlespace awareness system. By using the system to analyze the effects of attacks on both sides of the battle, future commanders will be employing a “virtual OODA (VOODA) loop.” The VOODA system and its three-dimensional modeling of the battlespace requires understanding. Concepts such as nonlinear modeling and intelligent systems must be developed.

Nonlinearity, for the purpose of this discussion, is defined as an aperiodic equilibrium state of a dynamic system. A system in nonlinear equilibrium seems to wander randomly, yet the behavior is deterministic. If you know the equations, you can predict in advance any point of the nonlinear path or trajectory.[24] The problem is in understanding how to model battlespace as the behavior becomes complex. Complex behavior implies complex causes. Events that are seemingly unpredictable, like a battle, are governed by many independent controls (such as individual commanders) or by random external influences (like weather).[25] Modeling a complex scenario requires a choice—either make the model more complex and more faithful to reality, or make it simpler and easier to manage. The simpler model is easier to produce and requires less understanding of all the complex factors involved, but will provide less useful results over time.

To tie this concept to battlespace planning, consider the current means of weather prediction. Complex algorithms and supercomputers produce a forecast with reasonable accuracy for a twelve to twenty-four-hour period; however, the farther into the future the model predicts, the less reliable the forecast. Currently, computing power struggles under the load of complex algorithms and the multiple iterations necessary for long-term accuracy. In 2025, predicted computing capability will give increased accuracy by allowing more complex algorithms to forecast events.

The data and software necessary for a VOODA loop system will be staggering, as will the required computing capability. The software that drives the system requires an adaptive "intelligent system" approach. An intelligent system implies multivalued or "vague" logic, or, simply put, "everything is a matter of degree."[26] An intelligent system learns rules from data or by watching the behavior of human experts through a network of sensors. The system with the greatest potential for military use is the fuzzy cognitive map (FCM) computer. An FCM draws a causal picture by tying facts, assumptions, and processes into values, policies, and objectives. It is designed to predict how complex events interact and play out.[27] An FCM has concept nodes and causal links. Concept nodes are vaguely defined sets like "tanks on a road" or "strength of a bridge." Causal links are vague rules that connect the nodes to show the effects of one node on another. FCMs thrive on feedback to determine which nodes are changing and by how much. The sensors of the future battlespace will provide the necessary data to the FCM. Intelligent systems are currently used in adaptive process controllers, air-fuel mixture ratio controllers, and automatic transmissions.

These and other areas of military and commercial applications could gain order of magnitude improvements. By allowing the commander the option of stepping forward in time, FCM using developed intelligent systems and simulation techniques offer great promise for improving cycle times in 2025. The ability to select the third move, based on the results of the planned second move, while the first move is taking place, represents an astounding improvement in cycle time. According to Noboru Wakami, a Matsushita engineer, "[intelligent systems are] like seasoning. Sometimes the seasoning simply improves the taste [of food]. Sometimes it produces something dramatically different."[28]

Summary

The interdiction mission in 2025 will require significant technological "leaps" to achieve the required accuracy, lethality, target detection, and cycle time. Penetrating sensors and designators coupled with microtechnology will permit weapons to have the processing power required to "touch" targets in exactly the right spot. Variable lethality will permit the option of killing, delaying, deterring, or breaking targets. Add intelligent system logic processing, improved target detection, and decreased sensor-to-shooter cycle time to these capabilities and the result is clear—airpower will dominate the battlespace.

Notes

[1] Hrand M. Munchenyan B. SC., E. E., M. SC., *Principles and Practices of Laser Technology* (Blue Ridge Summit, Penn.: Tab Books Inc., 1983), 96.

[2] Charles F. Meyers, *The Diffraction of Light, X-rays, and Material Particles* (Ann Arbor, Mich.: The University of Chicago Press, 1949), 284.

[3] "Fundamentals of Smart Weapons," Appendix 1 to Advance Sheet, Meeting 4, Report no. A304-4 (Fort Leavenworth, Kans.: US Army Command and General Staff College, September 1991), 82.

[4] Gerald Frost, *Operational Issues for GPS-Aided Precision Guided Weapons*, (Santa Monica, Calif.: RAND Corporation, 1994), 4.

[5] **2025** Concept, No. 20014, "Molecular Inertial Navigation Sensor," **2025** Concepts Database (Maxwell AFB, Ala.: Air War College/**2025**, 1996).

[6] *The American Heritage Dictionary*, (Boston.: Houghton Mifflin Co., 1982), 725.

[7] Maj Gerald R. Hurst, *Taking Down Telecommunications*, (Maxwell AFB, Ala.: Air University Press, September 1994), 29.

[8] Donald E. Tilley, *Contemporary College Physics* (Menlo Park, Calif.: The Benjamin/Cummings Publishing Co, Inc., 1979), 454.

[9] Robert Pool, "Atom Smith," *Discover*, December 1995, 56.

[10] Irvin Glassman, *Combustion Second Edition* (Orlando, Fla.: Academic Press, Inc., 1987), 1.

[11] Suzy Platt, *Respectfully Quoted, A Dictionary of Quotations Requested from the Congressional Research Service* (Library of Congress, Washington D.C.: Government Printing Office, 1989) 274.

[12] Ibid., 185.

[13] USAF Scientific Advisory Board, *New World Vistas: Air and Space Power for the 21st Century* (unpublished draft, the sensors volume, 15 December 1995), 92.

[14] *New World Vistas,* summary volume, 87.

[15] Ibid.

[16] Craig A. Rogers, "Intelligent Materials," *Scientific American*, September 1995, 124-125.

[17] Gabriel J. Kaigham, "Engineering Microscopic Machines," *Scientific American*, September 1995, 121.

[18] Ibid., 118.

[19] David A. Patterson, "Microprocessors in 2020," *Scientific American,* September 1995, 49-50.

[20] Kaigham, 120.

[21] Capt Richard E. Nock, "High Payoff Targets: When to engage," *Military Intelligence 19*, no 2 (Apr-June 1993): 19-23.

[22] **2025** Concept, No. 900385, "3-D Holographic Battlefield Display," **2025** Concepts Database (Maxwell AFB, Ala.: Air War College/**2025**, 1996).

[23] **2025** Concept, No. 900417, "Battlespace Awareness Holosphere," **2025** Concepts Database (Maxwell AFB, Ala.: Air War College/**2025**, 1996)..

[24] Bart Kosko, *Fuzzy Thinking, The New Science of Fuzzy Logic* (New York: Hyperion, 1993), 288.

[25] James Gleick, *Chaos, Making a New Science* (New York: Penguin Books, 1987), 303.

Notes

[26] Kosko, 292.
[27] Ibid., 222.
[28] Ibid., 183.

Chapter 4

Concept of Operations

We make war as personal as a punch in the nose. We can be selective, applying precisely the required amount of pressure at the specified point at a designated time-we've never been told to go down and kill or capture all left-handed redheads in a particular area, but if they tell us to, we can.

—Robert A. Heinlein

Some of these areas of enhancement do not represent, by themselves, revolutionary ways of doing business. Nonetheless, from today's baseline, each of the individual attributes—accuracy, lethality, target identification, and cycle time—will experience exponential growth. What is revolutionary, like blitzkrieg,[1] is the way these exponentially improving elements will be combined to accomplish interdiction—the interdiction system of systems. What follows is a description, based on the technologies outlined in the previous section, of a global attack system (GAS) in the year 2025. Our system is composed of four key subsystems: (1) a battlespace targeting system, (2) a networked sensor array, (3) a variable lethality, very smart weapon, and (4) a command, control, and communications system to tie these subsystems together.

Overseeing the entire interdiction system is "the man in the loop"—the joint force commander (JFC) and staff. The battlespace system contains numerous information filters to provide the appropriate information to the appropriate level, but targeting authority belongs to the JFC. Since all the players have access to the same battlespace data, the JFC has complete flexibility to delegate this authority based on the forces available, the campaign plan, and the desired effect on the enemy.

The brain of the interdiction system of systems is a **targeting system**.[2] The interdiction targeting process begins with the JFC, based on fused battlespace information, designating an area of interest to the targeting module. This module, located in either space, an uninhabited reconnaissance air vehicle,[3] or an

AWACS/JSTARS-like aircraft, collects data via multispectral imaging[4] and processes the data intelligently to identify potential targets of interest. After concurrence from the joint force air component commander (JFACC) or his designated representative, the targeting module initiates the launch of unmanned aerospace vehicles UAVs that contain the miniature sensors.

These sensors are dispersed in the target area and begin to relay information to the targeting module. The JFACC, based on the sensor information received and the offensive game plan, designates the exact target and desired level of destruction. The targeting module then launches nearby fighters, bombers, or UAVs, gives them initial target information, and “hands them off” to the sensor array. The air vehicles proceed to the target area and drop their sensor-controlled weapons on the designated targets.

The eyes, ears, taste, smell, and touch of GAS comprise a miniature sensor array.[5] This sensor array is composed of adaptive microscopic machines that, having been dispersed by UAVs, seek out and find “interesting items.” After attaching to items of interest, the sensors begin to talk to each other and form a network. As the network matures, it is able to determine what is a valid target and what is not, where the target’s most vulnerable points are, what weapons effects will produce the best results, and where living beings are located. The sensor array then relays this information to the targeting control system. This system now has enough information to match assets to targets, based on not only target type and destruction requirements but also on an assessment of collateral damage risk. Ultimately, the sensors pass some of this information directly to the weapon. Additionally, the sensor array is able to report level of destruction to the targeting control system, which can then update its target list and continue the process as required.

The business end of the GAS is the fist—the variable-lethality weapon.[6] This weapon, delivered by either a manned or unmanned platform, is the ultimate in sensor-to-weapon-linked technology with the ability to vary the effects of the weapon based on sensor input. Using the networked sensor array, a direct data link is established between the sensor and the weapon. This link serves two purposes. First, it provides exact location information to allow precise weapon placement. Second, using the information collected on the type of material and structure, the sensor adjusts the yield of the weapon to produce the desired level of destruction. For example, hard targets might require a higher yield, underground targets might require delayed fusing to allow penetration, flimsy aboveground structures might require an airburst to maximize blast, and so forth.

In addition to adjusting the bang, based on target requirements, the weapon is also able to flex to a nonlethal mode of operation. When the sensor array "notices" items whose damage or destruction would hamper the commander's strategic effort, the sensor-weapon link would reduce the yield and/or change the mode (e.g., blast to sticky ooze) based on preset or real-time operator inputs. One size truly fits all!

The final required element to allow GAS to function properly is a way to link the receptors, the brain, and the fist to one another, all under the control of the JFACC. We need a nervous system—a secure, high-speed, large bandwidth communication system—that will provide the required information flow. Although essential to our system of systems, this requirement is not unique to interdiction and is assumed to be in place.

The interdiction organism is now complete. It has a brain, an ability to sense its environment, a way to influence its environment, an ability to communicate amongst its various parts, and someone to tell it what to do. However, our interdictor can be rendered ineffective by attacking it at any of these points. The brain could be destroyed outright or infected with a crippling "disease." The eyes and ears could be "repelled" with an antisensor spray or, worse yet, information within the sensor net or from the net to the weapon could be altered (location, yield, etc.). The fist could be deflected or destroyed prior to target impact. The nervous system could be completely severed (electromagnetic pulse info weapon) or selectively disabled (spot jamming, etc.). All of these potential countermeasures will have to be considered and countered as we develop our "interdiction system of systems."

Having described the global attack system, a few caveats are in order. First, GAS is not delivery-platform dependent. As we progress toward 2025, new manned and unmanned platforms will be developed. GAS can be implemented on a variety of these platforms. Secondly, given the often uneven development of technology, advances in sensor technology may outpace that of variable-yield weapons. However, as pieces of GAS are completed, they can be implemented with a corresponding increase in capability. Finally, forward basing, if available in 2025, would improve the system response time. However, the impact of that decrease in response time is very situation- dependent.

Although GAS may do interdiction very well, a broader question must be answered. Does it answer the mail? Does this system satisfy the requirements identified for an effective interdiction system in the year 2025? The short answer is—YES! The critical force qualities required in 2025 are all satisfied by the various subsystems in our interdiction system of systems. For a detailed snapshot of force qualities versus GAS elements, see table 1.

As you examine this interdiction organism, a logical question is, "Why does this beast only do interdiction? Why not strategic attack? What about close air support? What is unique to the interdiction mission that limits this system's application?" The answer is—absolutely nothing! As our battlespace awareness increases, the artificial lines that divide the battlespace will continue to fade. This interdiction system can be effectively employed in the entire spectrum of attack operations, from strategic attack to close air support.

Table 1

Force Qualities Summary

	GLOBAL ATTACK SYSTEM							
	BRAIN		SENSORS		FIST			
	Holographic Interface	FCM Computer	Multispectral Laser	MUGS	Nuclear IMU	Acoustic Prep Devices	Multi-beam Attack System	Variable yield weapons
DETECT								
Sensor Coverage			X					
Sensor Revisit Time			X	X				
Location Accuracy			X	X				
Environmental Availability				X				
Sensor Survivability			X	X				
Unobtrusive				X				
Completeness			X	X				
IDENTIFY								
Speed			X	X				
Accuracy			X	X				
Resolution			X	X				
Traceability			X	X				
Battlespace View				X				
Correlation			X	X				
DECIDE								
Speed of Decision	X	X						
Decision Basis Accuracy		X						
Decision Quality	X	X						
ENGAGE								
Range			X				X	
Accuracy			X	X	X		X	
Timeliness	X		X	X			X	
Desired Lethality			X	X	X	X	X	X
Multi-role (Flexibility)			X	X			X	X
SURVIVE								
Vulnerability	X	X		X				
Countermeasures	X	X	X				X	
Stealth	X	X		X				

Notes

[1] Blitzkrieg was a revolution in military affairs that combined evolutionary technology in a revolutionary way to outpace the enemy in the battle.

[2] **2025** Concept, No. 900859, "Space-Based Target Designator System," **2025** Concepts Database (Maxwell AFB, Ala.: Air War College/**2025**, 1996).

[3] USAF Scientific Advisory Board, *New World Vistas: Air and Space Power for the 21st Century*, summary volume (Washington, D.C.: USAF Scientific Advisory Board, 15 December 1995), 21.

[4] Ibid., 20.

[5] **2025** Concept, No. 900860, "Neural Net Sensor Array," **2025** Concepts Database (Maxwell AFB, Ala.: Air War College/**2025**, 1996).

[6] **2025** Concept, No. 900858, "Sensor-Controlled Weapons Effects," **2025** Concepts Database (Maxwell AFB, Ala.: Air War College/**2025**, 1996).

Chapter 5

Investigative Recommendations

This paper has identified a number of enabling technologies for the interdiction system of 2025. Some subsystems were highlighted: beyond-electromagnetic sensors; acoustic, penetrating, and variable yield weapons; sensory netting; energy and particle weapons; and a virtual OODA loop. From these, three technologies emerge. These are the critically enabling technologies which, if pursued, will provide the basis for an interdiction revolution. The first is nanotechnology for inertial measuring units, sensors, transmitters, processors, and locomotion. The second, nonlinear modeling and intelligent systems, will support the virtual OODA loop. The third is expanded use of the electromagnetic spectrum for weapon guidance and remote sensing.

Nanotechnology is critical because the sensing end of the system depends on it. To cover a meaningful geographic area, these sensor/processors must be produced in huge quantities at low cost. Industry, even now, produces vast quantities of such devices. One example is the microchip inertial measuring units produced for automotive airbag actuation. In the future, miniature mass spectrometers and "inexpensive chemical detectors" will be made.[1] Such machines could certainly be adapted to fill the sensing needs of our system. Built through use of microchip production techniques, these machines will easily possess the transmitters, processors, and receivers that the interdiction system requires.

As stated, this system will have the processing capability of modeling the battlespace with the fidelity necessary to predict the effect of the war fighter's next move. Today, we can predict the weather for a 12 to 24-hour period. The nonlinear algorithms used for this, combined with vast processing power, will be available in 2025. Today, we must begin to expend the effort to study and understand the battlespace in terms of chaos theory and fuzzy logic so its unique features can be modeled.

Exponential gains in computational and processing capability are necessary, but they will be a "given" in 2025. Individual computers in 2025 "will be as powerful as all those in silicon valley today."[2] Commercial enterprise over the next 30 years will provide substantial support for the development of nanotechnology and nonlinear modeling.

The third technology deemed critical is the expanded use of the electromagnetic spectrum. At first blush, this seems to have little industrial utility. Guiding a weapon to a precise location within a structure is not a peacetime pursuit, but unobtrusively examining the interior of a structure is commonly needed—for example, aging bridges require testing to determine their health. Perhaps mining and oil drilling operations could benefit from a Cat (CT) Scan/Magnetic resonance image (MRI) of potential sites.

Conclusion

Nanotechnology for inertial measuring, sensors, transmitters, processors, locomotion, and nonlinear modeling, as well as intelligent systems for the virtual OODA loop and expanded use of the electromagnetic spectrum for weapon guidance and remote sensing, are the key interdiction technologies for airpower focus over the next 30 years. They are derived by envisioning required capabilities, describing systems that might be used in 2025, and then consolidating them into a concept of operations. These futuristic ideas were identified through the timeless core competencies of precision and information dominance. The great visionary, William Mitchell, once said, "In the development of airpower, one has to look ahead and not backward and figure out what is going to happen, not too much of what has happened." This paper has looked ahead and offers direction to air and space professionals. All that is left is to act.

Notes

[1] Gabriel J. Kaigham, “Engineering Microscopic Machines.” *Scientific American* (September 1995). 118-121.

[2] David A Patterson, “Microprocessors in 2020,” *Scientific American* (September 1995). 48-51.

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