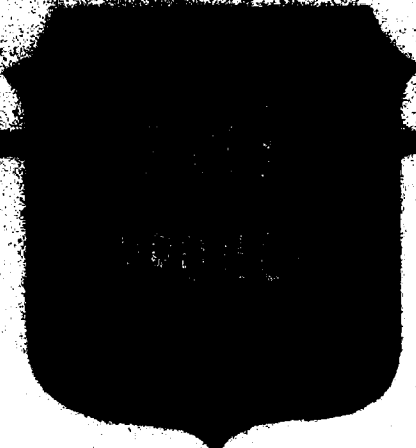


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MULTIBAND IMAGERY AND
THE OPERATIONAL LEVEL OF WAR

BY

LIEUTENANT COLONEL SAMUEL R. SCHWARTZ, EN

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USAWC MILITARY STUDIES PROGRAM PAPER

MULTIBAND IMAGERY AND
THE OPERATIONAL LEVEL OF WAR

AN INDIVIDUAL STUDY PROJECT

by

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U.S. Army War College
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MULTIBAND IMAGERY AND THE OPERATIONAL LEVEL OF WAR

CHAPTER I

INTRODUCTION

There is a direct relationship between the quality and effectiveness of decision making and the quality of data and analytical tools available to decisionmakers. Commanders' operational, planning and policy decisions are almost always based upon the recommendation(s) of some form of analysis which examines the interplay between several factors that impact upon a particular issue. Decisions concerning warfighting at the operational level, for example, must be based upon the evaluation of a host of institutional, political, historical, doctrinal and military specific concerns. Automated information systems based upon familiar geographic information standards (maps and related products) can enable the decisionmaker to deal more effectively with these issues. 1

Warfighting information systems are powerful tools for integrating and analyzing data derived from widely scattered sources as remotely sensed imagery, soils surveys, locally obtained special purpose maps, utilities maps, water sampling stations, topographic maps, municipal planning overlays and several social, political and economic agencies. Virtually any data that can be or are mapped to some geographic reference can be "digitized" and stored in a data base. Once stored these data can be rapidly recalled, manipulated, reconfigured, updated, compared, sorted, displayed and mapped at a scale and format designed to meet the needs of the commander and his staff. The system itself becomes a tool which allows decisionmakers an ability to analyze complex interrelationships (mathematical, social, spatial) between variables that affect a particular problem or situation. 2

The purpose of this paper is to look at a portion of information systems and surveillance technology supported by multispectral systems and multiband imagery and show how an initiative in this discipline would impact upon the Army's ability to accomplish its missions at the operational and tactical levels of war.

It follows that an information system derives its total power from two sources. The algorithms and composition of the logic, the analytical engine if you will, can be designed to support a host of input devices and data streams. However the strongest analytical model is limited by the quality and quantity of the data and sensor systems available to serve it. Multispectral systems providing multi band imagery data along with a host of other sources makes the analytical engine become a powerful information generating tool and decisionmaking aid. Warfighting information systems not only facilitate more timely, efficient and cost effective decisionmaking, they also foster better decisionmaking since they enable the user to conduct and derive information from analyses that were heretofore unique and otherwise infeasible.³

Warfighting at the tactical and operational level requires a multidisciplinary approach. Important contributions are made by maneuver, intelligence, logistic, engineer, signal, chemical and many other elements. The warfighting information system must be accessible to receive input from and provide information and support to all of these components. Institutional, doctrinal, political and economic considerations are oftentimes as or more important than technical issues. This important lesson must be applied in the utilization of a warfighting system.

On the battlefield of the future, "enemy forces will be located, tracked and targeted almost instantaneously through the use of electronic imagery, data links, computer assisted intelligence evaluation and automated fire control. With first round kill probabilities approaching certainty and with surveillance devices that can locate and continuously track the enemy the need for large forces to fix the opposition physically will be less important." This quotation is from an address made by General William C. Westmorland, then U.S. Army Chief of Staff, to the Association of the United States Army. He continued, "I see battlefields that are under twenty-four hour real or near-real time surveillance of all types. I see a battlefield on which we can destroy anything we locate through instant communication and almost instant application of highly lethal firepower."⁴

General Westmorland's vision is rapidly becoming reality because of developments in technology, specifically in the area of microelectronics. These innocuous chips in general and computers in particular have totally revolutionized

our lives. But these developments have revolutionized military activity to an even greater degree.

We are living in an era of technological growth with tremendous spinoffs to the military. Breakthroughs have occurred in several areas to include more efficient sources of power, improved fuels, reduction in size and weight per unit of destructive firepower, smaller more accurate weapons delivery systems and new materials, to include laminated armor and fiber optics. Of all the advances in military technology however, those with the most far reaching consequences are developments in surveillance used to locate, identify and monitor enemy forces and control the battlefield. 5

Coupled with microelectronics in the form of computers to assist in military decision making, advances in surveillance are transforming warfare at the tactical and operational as well as the strategic levels. Growth in technology and employment of new concepts and techniques for use on the battlefield of the future provides an awesome view of what lies ahead in warfare. Our primary national security policies call for the preservation of freedom for the United States primarily through deterrence of hostile attacks upon our nation, its people, military forces or allies. Should deterrence fail, America must be prepared to fight and defeat an enemy attack and terminate the conflict on terms favorable to the United States, its interests and its allies' objectives. 6 Deterrence is fundamental to our national strategy and is implemented through the provision of a credible warfighting capability to include the projection of combat power into whatever region it is needed. To deter effectively our strategy must meet four tests; survivability, credibility, clarity and safety. Its effectiveness lies in the minds of our opponents and their perception of what our capability may be. 7

A classic military thinker and strategist, Carl von Clausewitz, looked at deterrence in these terms. "Combat is the only effective force in war; its aim is to destroy the enemy's forces as a means to a further end. That holds good even if no actual fighting occurs, because the outcome rests on the assumption that if it came to fighting, the enemy would be destroyed. It follows that the destruction of the enemy's force underlies all military actions; all plans are ultimately based on it, resting like an arch on its abutment. Consequently, all action is undertaken in the belief that if the ultimate test of arms should

actually occur, the outcome would be favorable ... and relates not to the means but to the end." 8

Modern conventional warfare has become and will continue to be increasingly lethal. In the words of General John A. Wickham U.S. Army Chief of Staff in testimony to the U.S. House of Representatives Armed Services Committee on 5 February, 1985, "We are on the threshold of some enormous technological changes in conventional weapons. The yield of the weapons, the lethality of the weapons, the accuracy of the weapons means that we can build in the next four to five years, conventional weapons which will approximate nuclear weapons in lethality, and we are moving in that direction." 9

Interest is focusing on automated warfare. One reason is the lethality and destructiveness of future warfare and the inherent danger to people who must operate in that environment. Another reason is that technology to support sophisticated warfare is rapidly becoming available. Developments in surveillance and target acquisition systems, "intelligent munitions", advances in design of very destructive conventional munitions and the automation of command, control, communication and intelligence functions place today's ideas within reasonable reach. Finally, automated warfare becomes increasingly more palatable in an economic sense in that superior technology and its substantial reduction in the need for soldiers reduces the tremendous personnel financial costs faced by supporting a large standing army. More dollars can be applied to material investment and further development and enhancement of automated capabilities within a smaller defense budget. 10

Hard choices have to be made. Allocation of resources on the battlefield becomes a highly complex problem. Therefore decisionmakers wishing to effectively exercise their judgment must seek and receive assistance in dealing with complex and interrelated issues. It is for this reason that quantitative techniques have assumed such a rapidly growing role in a wide range of military decisionmaking situations. Multispectral imagery can and will provide the information needed for careful planning, situational analysis and decisionmaking on the battlefield where and when it counts.

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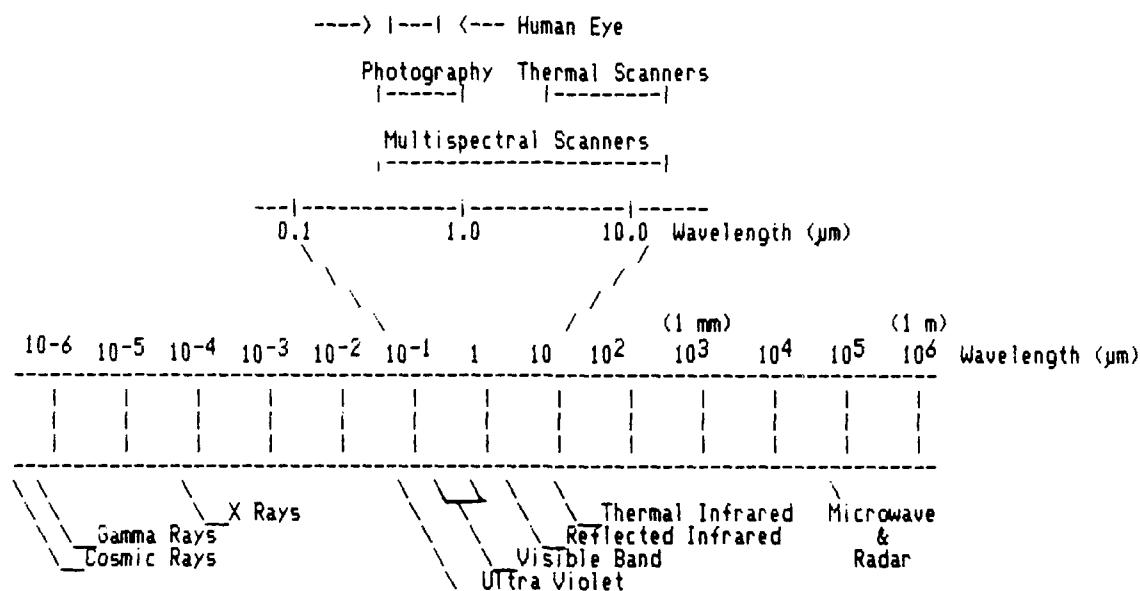
CHAPTER II

BACKGROUND

Remote sensing is the acquisition of information about an object taken without direct physical contact. The term, coined in the early 1960's by geographers in the Office of Naval Research, was used to apply to information derived from photographic and non-photographic systems. In a simple case the human eye may be considered a remote sensor because it visually senses information from its surroundings. However the term remote sensing as it is used today refers to the gathering and processing of information about our Earth and its environment, particularly its natural resources and the influence of man through the use of photographs, imagery and digital data acquired from an aerial platform or satellite. Remotely collected data can be in many forms to include variations in the geomagnetic field force distribution, acoustic wave or electromagnetic energy distributions. Most of the newer technology and, in particular, that with which we are concerned deals in electromagnetic energy systems. 1

The most familiar form of electromagnetic energy is visible light. The visible portion of the spectrum is only one of many forms of electromagnetic energy and makes up a very small part of the energy spectrum as shown below. With this band the human eye, panchromatic and color films as well as certain multispectral sensors are able to distinguish between shades of gray (intensity) and wavelength (color). Much information about the earth may be taken in the reflective ultraviolet, near infrared, thermal infrared, and microwave portions of the spectrum as well. Coverage of terrain masses in these portions of the electromagnetic spectrum must be obtained electronically using selectively designed sensors and scanning systems. Each object on earth reflects, absorbs or radiates in some portion of the electromagnetic spectrum according to its own particular structure, composition and condition. The frequencies of the reflected energy as well as their intensity are like a fingerprint which can help identify or characterize an object. These fingerprints are known as spectral signatures. 2

The Electromagnetic Spectrum and Spectral Characteristics of Sensing Systems. (Note that wavelength scale is logarithmic.)



Devices used to sense and measure reflected electromagnetic energy are known as multispectral scanners. The sensors sweep over areas of the earth recording strips of spectral fingerprints in small units called pixels. Depending on the design of the sensor and many other factors pixel size resolutions range from approximately thirty meters square to much less than one meter. These pixels can be reconstructed mathematically as if they were a map. But here is where the real power of multiband imagery shows because the positioned data can be further analyzed through comparison and frequency band ratio techniques to force selected fingerprints or characteristics of interest to stand out and be measured. The military implications of this capability are obvious. 3

The identifying, measuring and accounting for resources over large areas of the globe and deriving specific information about them is a formidable task. Today's technological advances in the fields of sensors and high speed computers able to manipulate the massive data streams related to terrestrial information management provides the potential to produce reliable information bases at spatial, spectral and temporal resolution that is useful to both military planners

and land use managers alike. The reader interested in historical or more technical information about remote sensing and multiband imagery is referred to several excellent references listed in the bibliography.

What follows is an attempt to examine the information requirements and decisionmaking needs of a commander functioning at the operational level and suggest that multiband imagery, when quickly converted to militarily significant information can have a major impact upon his decision cycle. It must be pointed out that the use of remote sensing or any other data for military applications is highly sensitive. Any concepts, requirements, capabilities or applications discussed in this paper are strictly the hypotheses of the author and must not be taken as official positions.

Airland Battle doctrine portrays a situation characterized by non-linearity and fluidity. The successful commander, both at the operational and tactical levels, must maintain a degree of purpose, coherence if you will, in order to confidently concentrate superior combat power at decisive places and win battles and campaigns. Certain operational functions traditionally associated with tactical operations may be used by the operational commander. These functions applied at the operational scale change the way they are conducted and synchronized. The operational commander must influence the design and desired outcome of his campaign well before its actual conduct since operational decisions carry great inertia, are not easily changed and the consequences of failure are significant. 4

Intelligence has been defined as the product resulting from the collection, processing, integration, analysis, evaluation and interpretation of all available information concerning foreign countries or areas which is significant to military policymaking or the planning of military operations. Timely, accurate information about the activities, capabilities, plans, intentions and actions of an enemy (or a potential enemy) is needed to develop sound national security and foreign policy and workable operational plans. The functions of intelligence and deception allow the commander the luxury to directly influence the outcome of the operation. The concepts of intelligence and deception are really direct opposites in that deception deals in self analysis as opposed to enemy analysis, yet the elements of

deception from the enemy's point of view are essentially the same as our intelligence efforts directed at an enemy force. 5

Situation development becomes the basis by which intelligence is developed at all levels. Data elements are gathered and processed into information which is further collected and fused into a product derived from multiple sources to provide the commander an estimate of the situation in sufficient time to allow him to respond with the most effective friendly course of action. The commander and his staff consider the well known factors of METT-T, the mission, Knowledge of the enemy, terrain, troops and time available. Intelligence is vital to the successful design of the operation. Difficult to achieve and dangerous to rely upon, intelligence at the operational level remains critical to the commander's decisionmaking process which carries momentum so that once put into motion cannot be easily redirected. 6

The operational commander therefore needs a dedicated system of intelligence preparation during peacetime to aid in planning at the operational level yet capable of providing the rapid response information and decisionmaking needs in sufficient quantity, accuracy and reliability essential to support his mission of deterrence through readiness, preparedness and vigilance. One part of those needs I believe can be satisfied by and through the use of a dedicated multiband remote sensing capability placed on orbital and airborne platforms.

The current military posture statement prepared by The Joint Staff reflects their recognition of the increasing military importance of space and our increasing dependence on space and aerospace systems for the effective employment of the United States' military forces. "[Aero]space based systems have clearly demonstrated their value in support of the planning and execution of U.S. military operations, thereby contributing to the deterrent and defense capabilities...National command authorities and U.S. military forces depend heavily upon [aero]space systems in peacetime, crisis and conflict." 7

Current military uses of space include collection of information about the weather, providing tactical and strategic communications and communications support, navigation and nuclear warning. Other areas of interest include space control, force application, space support and force enhancement studies and effects. 8, 9

Force enhancement activities applicable to provide intelligence support to the operational commander include communications, terrestrial surveillance, navigation and positioning, meteorology, oceanography, mapping and search and rescue. Space support activities include operations associated with the launch, deployment, maintenance, sustainment and recovery of aerospace vehicles and their mission oriented subsystems. 10

Space systems have been designed to support both peacetime and wartime military operational requirements within these previously noted areas. Many functions and capabilities provided by orbital systems are unique and cannot be duplicated by airborne or ground based systems. Other functions become enhanced by the positional or temporal aspects of space basing and provide increased force multipliers for the operational commander by helping him more effectively predict conditions well into the future in the face of an enemy revealing his operational aims and reducing the factors of uncertainty. 11 Analyses derived in part from multiband imagery provide the commander an idea of just what his operation appears like from an enemy's perspective thereby providing a twofold advantage. His overall control of his own widely dispersed force is greatly improved and what may be his most important battlefield initiative, his intent to deceive, becomes less vulnerable to discovery. Dedicated information systems supported with multiband imagery lets the commander better see the current battlefield at a macroscopic level. They provide a cushion of redundancy, an overlap if you will, with scarce national systems' information, thereby giving the operational commander a high degree of confidence in the information he is receiving for use in his long range planning and decisionmaking process from his own systems.

In summary, theater commanders must apply the principles of war and accurately identify and defeat the enemy at his center of gravity. 12 The successful commander should have sufficient high quality information in as near real time as possible so that he can intimately understand his enemy, unmask his motives and operational scheme, "walk a mile" in his opponent's shoes, and then attack him with certainty at his center of gravity. Multispectral systems can play a major role by assisting pre-war intelligence preparations and indicating, in harmony with other resources, those changes that give the commander the information he needs to fight.

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CHAPTER III

THE REQUIREMENT AND A SOLUTION

Maneuver commanders at the operational and tactical level require several varieties of relevant, high quality information covering extensive areas of terrain in order to adequately plan and conduct their operations. These information packages include previously developed long term data base reference resources upon which current remotely sensed data and information may be overlaid, correlated and analyzed. They can provide the commander the edge he needs to better understand the enemy he is facing and hopefully shorten his decision cycle to one well within that of his opposing counterpart in order to take charge of the operational battlefield and win decisively. The information needed at the operational level, while composed of many elements of analysis that are included in tactical information needs, must be evaluated in a wider context in an effort to learn their effects upon the enemy's decision making process. The operational commander must merge political, economic, technical and temporal information normally associated with strategic collection means. It is likely that he is one of several customers competing for access to these highly specialized limited information sources. This situation is unacceptable! 1

Today's commander in chief (CINC) must operate within the entire spectrum of modern warfare. He must be prepared to deal with application of military power using small, highly specialized forces to achieve national aims short of general war to massed armies, air forces and navies conducting joint interdependent operations on a regional or worldwide scale. As his scope has broadened so have his problems of planning and command and control of these military operations at the macro level. 2

The operational commander must have dedicated systems, capable of providing a stream of both strategic and tactical level information in a real or near real time basis tailored specifically for his region and expected level of application of power. What must this system be capable of doing? What are its key characteristics? Where should its component parts be found on the battlefield? When should it be available to the operational commander? How does this

capability impact upon the doctrinal, training, organizational and material needs of our armed force? What follows is an attempt to address these and other issues.

An Evolutionary Expert Information System For Battlefield Analysis (EEIS) may provide a solution. The term expert system requires some further explanation. An expert system consists of an automated logical decisionmaking and analysis process that uses data and inference procedures to solve non-trivial problems that are difficult enough to require significant human expertise for their solution. Founded on knowledge built up by experts in the field and stored in an automated information base, the system applies and processes that knowledge through interaction with some inference or logic driver which controls the reasoning process. Key to the success of expert systems is separation of the information elements and the procedures of applying that resource to practical problems. Separation facilitates changing or updating the system as new understanding is acquired either through the data or inference lobes. 3

Simple in concept the EEIS consists of a variety of multispectral sensors mounted on one of several suitable aerospace platforms. The multiband sensor bank would have sufficient resolution and bandwidth structure capable of sensing data from a designated area of interest within the prescribed wavelength bands and passing that data to a receiving and analysis station or battlefield scenario generator (BSG). 4 A key feature of the multiband scanner is its ability to be preprogrammed to sense, on a priority basis, for specific factors associated with weather, terrain or intelligence. Special combinations of sensor selection and sensitivity or a general default value capable of selective or general data acquisition may also be chosen. It is here where analysis rules, archival data and current multiband imagery data input are merged and processed in order to provide real time battlefield situation information to the commander and his staff. Additional off-line controlled processing may also provide a wealth of information for inclusion in baseline intelligence products such as the intelligence preparation of the battlefield (IPB) enemy, weather and terrain analysis. The BSG would merge current input with its terrain, feature and military data bases and extract relevant battlefield information reports. The BSG will use its expert systems logic, capable of examining past and current information about a particular area or region, and automatically predict (on a

statistical basis) current and future effects the weather and terrain will have upon enemy and friendly operations. 5

For example, the EEIS will have as one kernel a paradigm of say tank mobility based upon terrain characteristics, features, soil types, vegetation cover, expected seasonal norms, current and forecast weather conditions, vehicle characteristics enemy order of battle and other variables. It will then merge this mass of data into a clearly defined mobility analysis on a pixel by pixel basis for the area in question. 6

The multispectral scanner package being relatively small and light weight may be installed on one of several space and aerial platforms capable of performing reconnaissance missions in the desired area. Since the system is programmable, mission controllers will preset the desired spectral characteristics, scan rates and resolving power required for the type of mission being planned. Having the flexibility of mission priority programming and selecting the appropriate one of several aerial platforms the system can be directed at obtaining additional information about the enemy, weather or terrain from a variety of terrain parcels located from just behind the forward line of troops (FLOT) to regions deep within enemy territory.

Information to support the following operational level of war requirements is forthcoming from such a multitask oriented system:

- Situation development - IPB development and refinement requires a continuous integrated analysis of weather terrain and enemy capabilities upon operations. Current characteristics of the theater of operation and changes on a macro- as well as on a microscopic perspective are important. Threat evaluation to include force to space ratios derived from enemy deployment patterns, echelonment of forces, composition of forces and terrain analysis may be determined through multiband imagery.

- Target development - Multiband imagery provides the capability of sensing significant current events on the battlefield and quickly mapping them for use as analytical tools to determine enemy campaign characteristics, formations and possible center(s) of gravity.

- Security and deception - Multiband imagery allows for the depiction and determination of measures used by friendly forces to protect their own centers of gravity and enhance their degree of survivability. Coupled with decoy and deception planning, multiband imagery allows the operational commander a view of how he looks to the enemy and where his deception actions need strengthening.

- Indications and warning - The rapid response and long term surveillance characteristics offered by multiband imagery provide the luxury of observing changes in economic, agricultural, social, industrial and military behavior patterns that could indicate potential enemy hostile actions.

These characteristics are useful to the commander to plan, control and monitor his operational maneuvers while remaining abreast of enemy activities. Maximum use of his limited resources can be planned to both optimize position of his forces on the battlefield and exploit tactical success to achieve national aims and strategic results. 7

Survival of the EEIS on the battlefield is critically important. Location of its components and their ability to link with the BSG and associated expert analysis system is synonymous with success. Redundancy is one means of insuring the survivability of EEIS. Mounting multiband sensor packages on a variety of platforms and providing both on board recording and downlink capability of such design and characteristics to avoid detection enhances survivability. Positioning receiving antennas as far forward as practicable and using reduced power and line of sight transmissions assists as well. For missions requiring long duration data streams, on board recording and mechanical delivery of recorded data provides added survivability and limits detection. Use of ground generated signals to mask real downlinked data streams allows long term transmissions to be made with relative safety. Orbital platforms may transmit data through orbital or ground based relay stations. Once received, data can move rapidly through fiber optic or hard wire ground communications nets until it reaches the BSG complex. BSGs can be positioned in corps or higher headquarters intelligence modules in accordance with current doctrine and battlefield dispersion methods. Once converted to information formats, multiband imagery derived products can be dispersed to higher and lower echelons as necessary through existing distribution means. 8

What remains to be discussed deals with doctrine, training, organization and material acquisition, or in simpler terms, integrating multiband imagery into the force structure. Since this paper uses no classified information or ideas, I will attempt integration of EEIS with hypothetical deficiencies, descriptions and driving factors and will propose corrective action methodology which can be used to get this capability into the force, more specifically, into the hands of the CINCs and corps commanders.

As stated previously, Operational commanders require a dedicated source of information covering areas of terrain ranging from a few square kilometers to large regions greater than one million square kilometers extending from the FLOT up to several thousand kilometers behind enemy lines. An EEIS capable of meaningful accurate assistance in the analysis of the several oftentimes complex variables, accepting multiple data inputs and programmed with pre established decisionmaking criterion would provide the CINC the tools needed to speed his decisionmaking process in the conduct of military operations. One source of data input, multiband imagery, can be exploited for the enhancement of targeting, terrain analysis, weather and other factors concerning enemy and friendly forces. Considering the individual and synergistic capabilities of multiband imagery sensors mounted on several types of space and aerial platforms, the ability to manipulate their data streams and quickly correlate findings to a geodetic reference and the ability to tie these products in with conventional IPB, terrain analysis, weather, targeting and situation development makes multiband imagery an ideal selection.

What then is our goal and how can it be reached? The Army must develop a capability to collect and analyze a variety of digital multispectral data products keyed towards support of its warfighting CINCS and their major subordinate commanders in planning and conducting joint and large unit operations. This capability must include rapid analysis, via knowledge based automation or artificial intelligence systems, of terrain, weather and enemy information data. Data must be acquired at appropriate levels of sensitivity and resolving power and in selected spectral bands in order to quickly provide the required information to the decisionmakers. The exploitation of aeronautical and space related technologies is emphasized since these disciplines most likely hold the

capabilities of evaluating, analyzing and displaying situational parameters on terrain based graphics at the scales necessary to support the region. 9

We start with the cooperative participation of terrain and intelligence analysts capable of merging the intuitive powers of their Digital Topographic Support System and the All Source Analysis System or their derivatives. Key to operational capability is the ability of these two battlefield analysis disciplines, each with their respective data base management responsibilities, to use one-another's working files. With the introduction of multiband imaging technology, immediate attention is to be given to continued building of data bases and libraries. When the expert automated management and decision capabilities become available, incorporation of these libraries will enable rapid and accurate interpretation of critical features and attributes which feed the decisionmaking process. Concurrent structured professional resident and field training programs must be established, training devices fielded and formalized doctrine developed. 10

A listing of significant integration issues follows:

- Doctrine -

- * Develop processes and planning procedures for obtaining, managing and using dedicated EEIS capability at the operational level.

- * Develop doctrine to interrelate multiband sensed digital imagery and conventional analog products.

- * Develop the logic flow architecture and inference rules/decision processes for use in the production of automated information.

- Training -

- * Institutionalize military space engineering research.

- * Develop a program of instruction for integrated multiband imagery analysis. Establish training requirements for officer and enlisted personnel in this field.

- Organizational -

- * Establish organizations for planning, controlling, analysis and presentation of multiband imagery information products.

- * Create an active space developments working group

- Material -

- * Develop and field multiband imagery capable acquisition and analysis systems.

- * Upgrade and improve terrain and intelligence analysis workstations, within DTSS and ASAS and respective training devices.

- * Develop and field standardized digital informational data bases capable of multiband imagery data compatibility, advanced analysis workstations and training devices.

- * Develop and field imagery correlation software to support terrain and weather analysis, situation development, target development, security and deception and indications and warning for the EEIS.

Up to this point I have presented a group of issues general in nature which in themselves present a formidable problem. When examined under a higher degree of magnification certain implications and possible solution strategies become apparent. My aim is to break the EEIS integration problem into smaller more manageable pieces which may provide a source of requirements for further action.

11

- * Develop processes and planning procedures for obtaining, managing and using dedicated EEIS capability at the operational level:

Assuming dedicated multiband imagery based data acquisition support was available for the warfighting CINCS and their major subordinate commands, no battlefield scenario generator exists which can quickly convert the high volume data streams into a useful information product. ¹² Even if such a capability existed the analysts have no real means or procedures to capitalize on its availability due to a lack of standard methods and techniques at their level. Procedures for requesting, obtaining, processing, analyzing and exploiting multiband imagery technology are lacking. Design of automated data bases capable

of storing and accessing raw mission data or interim information products is yet unspecified. No appropriate standard exists for exploitable digital multiband imagery data. Current publications make no attempt at incorporating this technology into daily operations. Solutions to this issue require merging the multiband operational capability with product requirements, planning and management procedures and published doctrine.

* Develop doctrine to interrelate multiband sensed digital imagery and conventional analog products:

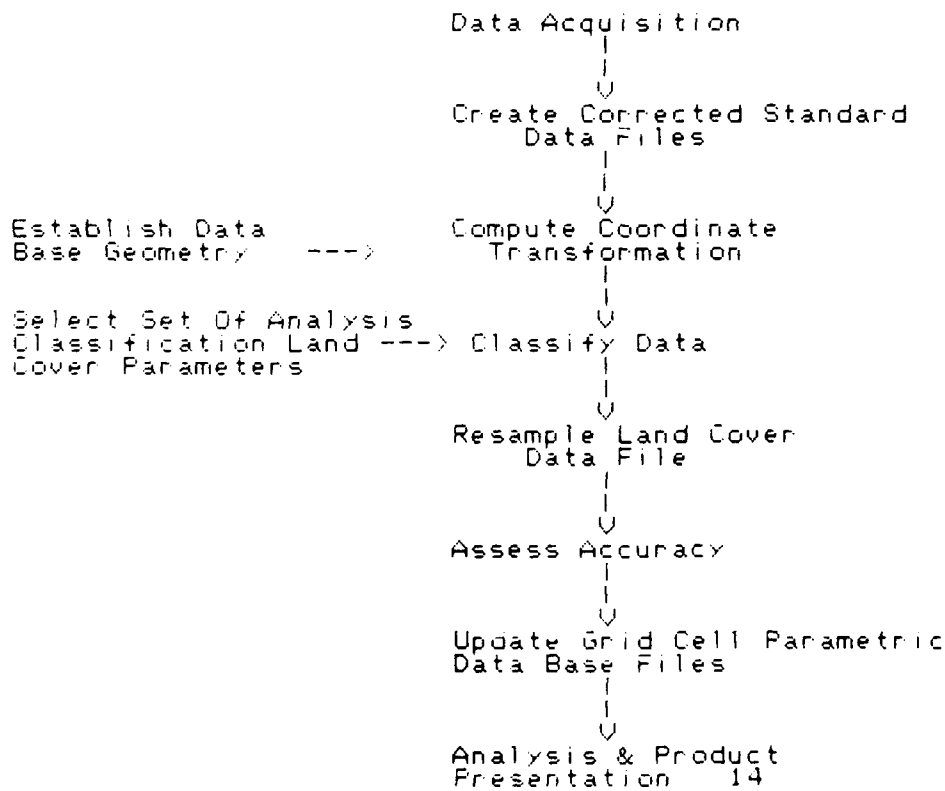
Multiband imagery can provide specialized image based products which exploit the unique features of spectral data; the ability to draw inferences through mathematical interrelation of two or more spectral data bands acquired over time. More work needs to be done in developing procedures of pattern recognition and analysis of weather and terrain features typically associated with military activity. Multiband imagery technology is expanding today at a very high rate. Imagery patterns associated with activity important to the operational level commander and the variety of terrain features discernible in digital imagery analysis is poorly understood and not well documented. Recognition and identification of high value targets with operational importance using digital multiband imagery is poorly understood and not well defined. Manual techniques are used almost exclusively at corps and below due to limited computer support. Multiband imagery analyses can include the effects of change over time yet no doctrine for temporal analysis of terrain and target attributes modified by the presence of military activity has been developed. Procedures to correlate terrain and target pattern changes over time must be developed. The sensitivity of discernible reflectivity and emissivity properties of terrain, vegetation, military equipment and vehicular signatures is not well understood or documented. Change detection of high value targets of interest by multiband imagery sensors using digital formats requires further study. 13

* Develop the logic flow architecture, inference rules and decision processes for use in the production of automated information:

Digital multiband imagery data may be obtained by a variety of multispectral scanning systems mounted on one of several orbital or aeronautical platforms. This implies data sources of various scales using sensors with particular

sensitivities to certain spectral bands. Can such a variety of multiband imagery data be meaningfully used by any analysis system? Do pre-processing requirements exist to bring the multifaceted data into some degree of standardization before it can be used? Procedures must be developed to allow comparative manipulation of digital multiband imagery with conventional analog (photography) as well as other image based, signals, scientific and technical and human intelligence based products. Obstacle information, terrain and weather data bases must also be included and brought into the same degree of standardization. Current manipulation of digital multiband imagery is limited to algorithms and heuristic procedures performed on individual bands of data derived from a pre-determined mix of spectral bands.

An analysis architecture could look something like this:



- * Institutionalize military space engineering research.

Our officers are in most cases ill equipped to advise commanders on the use of aerospace related engineering capabilities like multiband imagery. Junior officers are generally unable to conduct technically oriented research and are not suited to perform engineer intensive duties that are not well defined or promote better understanding of their professional field through publication. TRADOC schools must establish professional standards and encourage junior officers to develop in technical fields without fear of stagnation or non-selection. 15

- * Develop a program of instruction for integrated multiband imagery analysis. Establish training requirements for officer and enlisted personnel in this field:

Multiband imagery is a relatively new discipline with efforts at major universities aimed at broadening the knowledge base. Only a few universities have programs dedicated to the analysis of multiband imagery products in digital and graphic form and none have programs suitable for terrain or intelligence analysts who would work with these materials in the military. Terrain analysts receive only cursory training in hard copy format analysis of multiband imagery products. They are not currently trained in manipulation of various sources of digital multiband imagery nor do they receive instruction in analysis of multiband imagery data through the use of user responsive decision aids. No training is offered to analysts in the rigorous correlation of terrain features and attributes as they relate to or are modified by military activity, time or a host of other variables.

The Defense Mapping School has initiated development of several new courses with completion targeted for late this year. Germane to this discussion is the Introduction to Multispectral Imagery Course (IMSIC) which will provide an orientation on mapping charting and geodetic applications of both hard copy and digital LANDSAT and SPOT satellite imagery. This course is definitely a step in the right direction. 16

Officers and warrant officers remain poorly equipped to actively participate in multiband imagery technology. Since no real opportunities for formal military schooling in this discipline exists interested individuals must compete for limited resources to study under advanced degree completion programs. Programs in the fields of knowledge engineering, geological engineering and remote sensing

must be established. Multiband imagery will become a key contributor to the warfighting ability of our CINCS. Requirements will grow and mature to provide a balanced number of officers and noncommissioned officers capable of operating multiband imagery processing and decisionmaking systems. TRADOC should specify the detailed needs for these specialties now and develop in-depth programs at the U.S. Army Engineer School, the U.S. Army Intelligence School and with industry to satisfy the future demand for skilled managers and operators. It is only through educational programs and adequate career progression paths that skilled military people needed to support and grow with these state of the art systems may be trained and retained to meet the high technology demands posed by EEIS. 17

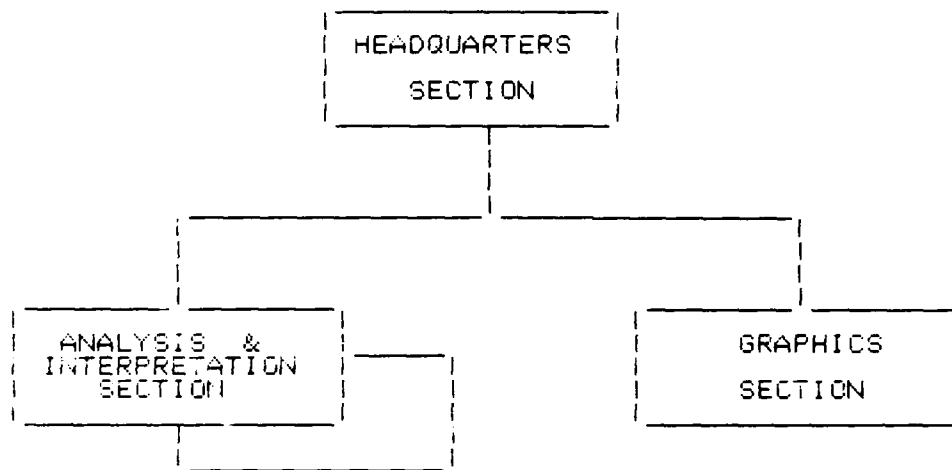
* Establish organizations for planning, controlling, analysis and presentation of multiband imagery information products:

Limited organizational capability for multiband imagery exploitation exists at very high echelons and are staffed with specialized Department of the Army or Department of Defense civilian employees. Usually no "green suited" multiband imagery exploitation capability exists in direct support of a CINC. What would such an organization capable of multiband imagery information require, how large should it be, and what should its organizational structure look like?

A multiband imagery exploitation team, capable of receiving, processing and analyzing data and producing useful information products should by necessity be small. Based on living (L series) TOE design philosophy it should have a headquarters module, at least two data reduction and analysis modules and one graphics product production module for round the clock sustained operational capability. The headquarters module should have an officer, perhaps a major but at least a captain as well as a technical warrant officer and a senior noncommissioned officer (E7). Each data reduction and analysis module should be manned with a NCOIC (E6) and a mix of enlisted data reduction and data interpretation specialists (2 ea E5 and 4 ea E4 and below). This mix allows the module to task organize itself to meet workload demands. The graphics support module should also be run by an NCOIC (E6) with two teams of cartographic craftsmen and graphic arts specialists each staffed with an E5 and 2 ea E4 and below. There will be a requirement to develop new military occupational specialties (MOS) skills in the multiband imagery analysis and interpretation

field. The teams will be attached to a military intelligence battalion for their normal support but would receive their taskings through the intelligence channels. I envision the team receiving data to be analyzed in the BSG or working with products for further analysis and presentation. The graphics support team would be equipped with a Quick Response Multicolor Printer while the analysis team would have a Terrain Analysis Work Station at its disposal. Final team manning would be dictated by the other equipment and transportation related workstation system personnel needs.

Multiband Imagery Exploitation Team



* Create an active space developments working group:

The Army Engineer community is currently supporting remotely sensed data and its implications at the U.S. Army Engineer School and three laboratories, The Cold Regions Research Laboratory, The Waterways Experimental Station and The Engineer Topographic Laboratory. Several other agencies to include The Space Division of Headquarters, Army Materiel Command, The Night Vision and Electro-optics Laboratory, The Office of the Surgeon General and The Army Medical Research and Development Command are actively involved in further initiatives. I am confident that several other agencies fall in the same category. A need exists for a forum to address multiband imagery, artificial intelligence and other related disciplines of potential benefit to the Army and others. An Engineer Development working Group structured with a steering

committee and sufficient subject area panels (such as multiband imagery and professional development and education) could formulate potential warfighting information systems and related applications. It could serve as a nucleus of concepts, techniques and accelerated application for the Army.¹⁸

* Develop and field multiband imagery capable acquisition and analysis systems. Upgrade and improve terrain and intelligence analysis workstations, within DTSS and ASAS and respective training devices. Develop and field standardized digital informational data bases capable of multiband imagery data compatibility, advanced analysis workstations and training devices. Develop and field imagery correlation software to support terrain and weather analysis, situation development, target development, security and deception and indications and warning for the EEIS.

Potential military users of geographic information systems have growing needs for several varieties of digital geographic data bases. A multiband imagery and recording system will provide for near real time collection of terrain, weather and feature oriented data through several spectral bands and offer the user the option of on board data recording (for processing after completion of the data gathering mission), real time data transmission (for immediate exploitation by a local BSG) depending upon the structure of the mission or a combination of the two. A pre-selected weighted mix of those spectral bands of real time interest eg. targetry will simultaneously be transmitted to telemetry facilities for pre-processing and use at EAC or at tactical levels. Depending upon the sensor package design and the selected platform, the multispectral system will be capable of self operation and key on other on-board searching sensors (position, sun angle, altitude, time, etc.) and intelligently select appropriate spectral bands to record or transmit in accordance with the mission parameters.

The telemetry or preprocessing facility must be capable of survival on the battlefield and allow for rapid mission planning, acquisition and preprocessing of downlinked digital multiband imagery data. Pre-recorded data must also receive preliminary processing into standard formats and then be fed into the BSG's geographic analysis capability.¹⁹ Conversion of current data and existing data bases into information graphics that key on operational or tactical requirements now provide the commander and his staff with an enhanced warfighting decisionmaking capability. New information is merged into the BSG's information

data bases in order to have the most current information tailored to the specific needs of the region.

The software architecture capable of supporting the EEIS must be based upon the selected host computer's design, operating system, graphics capability and data base management system. Applications software can be tailored to problems that are process oriented, discipline or functionally related. Functionally related software would fill modeling requirements such as scanned data capture and raster correlation, image display and analysis, terrain modeling, feature analysis, and geographic/spatial analysis. Discipline related software is designed to meet the needs of the individuals trained in the mapping sciences who require a family of approaches to solving problems involving the geodetic survey, photogrammetric, geophysical or cartographic fields. Terrain analysis classification software provides on-line interactive study of terrain features typically associated with military activity and enemy order of battle doctrine. Detection of change due to military activity or other preparations for war will be highlighted for further analysis and verification. This software will be in the form of a user friendly expert design that allows on-line knowledge base updating, information retrieval and rule adjustment to account for special case analyses. The rule patterns must be selectable for use of this software at corps or EHC levels. Compatibility with data bases supporting DTSS, ASAS and their derivatives is required. All software will support the analyst at his workstation.

The analyst's interactive workstation will allow for the manipulation of digital multiband imagery data, other data sources, and existing information data bases using a variety of algorithms and procedures. The workstation will also provide for comparative analyses through manipulation of digital multiband imagery with photographic, locally forecast weather, and other layered sources of managed data (obstacle plans, artillery data bases, terrain information systems) and operate interactively with intelligence sources and analysis systems. Output will include perspective views, thematic and planning maps, feature overlays and other custom designed products. 20

Analysts will be provided training at their workstations with realistic multiband imagery derived data with which they can interact and compare. Other data inputs as previously described must also be made available to allow them to

develop the experience and capabilities in peacetime that they will exercise in war.

Use of multiband imagery and spectral data reconnaissance systems supports continued growth in equipment that makes aircraft, helicopters, remotely piloted vehicles (RPV), satellites and other platforms more effective. Enhancements in sensor technology do not add to the cost of the means of their delivery and therefore supports national budgetary goals. Ground based systems must survive which implies rapid setup and teardown times and mobility thereby decreasing exposure to the threat. The multiband imagery package can be mounted on any of several platforms however only state of the art improvements can reduce time over target, vulnerability to weather and enemy air defenses and dependence on forward airfield basing. 21

In this chapter I have attempted to address, in general terms, the more important doctrinal, training, organizational and material issues facing the integration of a warfighting geographic information system. The operational commander must have an enhanced decision making capability to compress the time required for his decision cycle so he can meaningfully influence the battlefield. Emerging technology, especially in the field of microelectronics and the ever growing requirement to manage through rapid analyses, planning and reporting will provide the medium for developing military geographic information systems and battlefield scenario generators. One can draw a parallel here to the now familiar executive decisionmaking tool, the spreadsheet. What the spreadsheet did for economic analysis geographic information systems can do for military decisionmaking. For the first time people from a wide range of fields can quickly and easily see geographically tied feature relationships, can manipulate the information to suit their needs, define new boundaries and confidently make decisions. The range of potential application for the military is staggering and is limited only by the imagination and skill of the personnel involved.

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CHAPTER IV

APPLICATIONS

Up to this point I have looked at national and military strategy and identified a generic requirement which when filled would better enable operational level commanders to meet the needs of that strategy. The concept of the EEIS and BSG, able to receive, manipulate and analyze data from several sources to include multiband imagery, equates to a highly specialized geographic information system which focuses upon the needs of operational level decisionmaking in peace and across the entire spectrum of war. Any system that can so intervene in operational and tactical warfare obviously has several uses and applications, some of them satisfying critical needs. Depending on the resolution and discriminating powers of its sensors and the analytical power of its computers, the EEIS holds almost unlimited potential. One needs only to investigate a few possible applications of this discipline in order to grasp the tremendous advantage having such a capability would allow. Terrain shaping and crisis management are two subjects of significance to operational warfighters that lend themselves to augmentation through an EEIS.

A new generation of obstacle producing systems to include scatterable mines (mechanically, aircraft and artillery delivered), off route mines, liquid explosives and manually placed mine systems with "smart" automatic and controllable fuse mechanisms is being developed and fielded. These systems have a tremendous effect upon the range of military, political and diplomatic options available to American leaders in time of increasing tensions. Considering crisis and conflict between both the superpowers and regional nations as well, the availability and in-depth employment of obstacle systems would significantly diversify American options, constitute a versatile lower rung on the escalation ladder and increase the United States ability to protect its security interests abroad.

The theater commander must be able to probe the mind of his opponent yet be able to show American resolve and solidity of purpose. The deployment of obstacles as a purely defensive measure provides him another in a range of options which in the end could unify allies into a strong willed force and shape the

battlefield in operationally advantageous ways. Due to the passive character of obstacle systems the aggressor, through his own actions, would activate and detonate a portion, perhaps causing him to rethink his position.

Ground forces have a strong requirement to locate surface laid minefields at stand-off distances from the main force structure in excess of ten kilometers. This gives the tactical commander the opportunity to decide if he will breach, bypass, clear or choose some other course of action available to him. This requirement is driven by the tactical emphasis of mobility, the developing tactics of enemy forces and the threat presented by introducing air delivered scatterable mines within the offensive structure of the hostile force. Standoff requirements remain in force for both conventional and scatterable mines. Enemy force doctrine, as ours, calls for the use (or re-use) of conventional surface placed anti-tank mines as flank protection during the attack. Other requirements for minefield detection include administrative clearing of mines after cessation of hostilities and for clearing operations in rear areas.²

Current safe techniques under study to satisfy the minefield detection problem relies upon acquisition of digital high resolution multiband imagery and a logic analysis algorithm which allows identification and detection of minefields on the battlefield. The hardware concept and software design successful in identification and location of minefields lend themselves as a small scale model for our EEIS battlefield information system. Having sufficient baseline data from which to compare those radiant and reflective changes pertaining to minefield detection is key to the success of the analysis. Furthermore, newly acquired data can be added to existing digital data bases thereby allowing better comparative analyses. Requirements for mission definition, sensor and platform specification, data transmission (or on-board recording), and data display falls within the overall needs of the EEIS, its supporting organization and equipment.³

A solution to this problem is by no means trivial. Once the imagery has been acquired the problem becomes one of information processing. Measured returns are dynamic, changing with weather conditions and time of day, and may only be an index of the unique properties being measured. Local background conditions (soil type, vegetation cover etc.) will also affect the solution. A correct analysis depends upon a "smart" computer capable of learning, a-priori those unique

properties of a minefield and using that as a point of departure for further analysis.⁴

The management of crisis involving a disaster or a scenario leading towards combat provides another lucrative area for the EEIS. The Crisis Action Systems Model used by our Joint Staff is a coordinated process that encompasses people, procedures and automated systems that together work to produce the best method of accomplishing a mission in the least possible time. The process provides information necessary to develop an appropriate response under time constraints.⁵ The crisis or disaster may form in a remote part of the world or within our own national boundaries. Key to emergency management is the crisis team's reliance upon some form of spatial presentation usually in the form of a graphic.⁶

Emergency managers and military leaders facing a crisis require a great deal of geographical information to include:

- Where are the impacted areas (area of interest)?
- Where are the people?
- What impact has key terrain and other natural features have on the operation?
- Where are the cultural, institutional and military facilities that play in this situation?
- What transportation options exist?
- What are the environmental pathways and likely avenues of approach?
- What jurisdictional boundaries apply and where do they lie?

These questions all focus on identification, location, change detection, pattern recognition and movement. The answers require a wealth of applied geographic knowledge as well as obvious spatial relationships to truly understand how the phenomena interrelate. Information extracted through analysis is mapped and presented usually in the form of an overlay.⁷

Hard copy map overlays suffer at least three limitations in crisis management situations. Time requirements may be greater for preparing overlay materials than the time frame in which necessary decisions must be made. Map overlays are prepared and used at only one scale thus limiting their flexibility for use in both general or detailed analyses. Finally, map overlays require mechanical and

analog methods of measurement making. The process of analysis with these tools is tedious at best.⁸

Geographic information systems code and store spatially ordered feature data and can easily retrieve, calculate, predict and present digitally derived graphics at whatever scale and information density is required.

Efforts at the Federal Emergency Management Agency (FEMA) are focused on deriving and programming logical algorithms to fit all conceivable disaster situations. As a result they have defined the information requirements and developed them for each major disaster related phase to include:

- preparedness
- warning
- emergency
- rehabilitation
- reconstruction

Data base preparation on a regional basis is well underway and are being established in a standard format ready for use in the same way wherever necessary. It should be obvious that crisis action, both in military and civil applications hold many similarities and developments in either area will complement each other.⁹

And the list goes on. Several other applications of the EEIS include navigation,¹⁰ civil works project planning,¹¹ reconnaissance,^{12,13,14,15} penetration of obscurant concealment,¹⁶ agricultural and economic studies^{17,18,19} and a host of others.

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CHAPTER IV

CONCLUSION

The previous chapters have looked at our national security objectives and the responsibilities placed upon our military forces to achieve them. Our joint doctrine calls for a unity of effort between Service forces which is realized only when the operational commander and his major subordinate commanders have sufficient geographic decisionmaking support to generate their critical information needed in time to influence the planning and execution of their operations. An initiative in geographic information systems and surveillance technology, supported by multispectral systems and multiband imagery, similar to the conceptualized EEIS and BSG that gives the commander dedicated, enhanced decisionmaking support was shown to increase his ability to accomplish his mission.

Colonel G.F.R. Henderson pointed out the same needs of the General In Chief almost one hundred years ago. "The explanation of the brilliant successes that the great generals gained in spite of rules and against enormous risks is to be found in the fact that they looked not only on the physical side - on the numbers and armament of the enemy - but that they saw his weaknesses; they played upon his susceptibilities and apprehensions; every movement that they made was calculated to destroy the moral and confidence of both general and soldier..." The successful commander, "looks across the enemy's lines, until he comes to the quarters occupied by the enemy's leader, and then puts himself in that leader's place, and with that leader's eyes and mind looks at the situation." and learns the weaknesses, presupposes the enemy's action and plans accordingly.¹

The issues which were previously raised - the information requirements of the commander, the development of information systems technology, the lack of dedicated expert warfighting information systems at the disposal of the operational level commander, proposed applications and the reliance upon manual methods and techniques to fuse snippets into information - are questions that must be addressed, now or at sometime in the future when their impact may be more severe. The longer these issues are postponed the more likely it becomes that our armed forces will be required to plan in a crisis management environment, where

alternatives are constrained by the time remaining in which a course of action can be implemented. Expert systems programs cross several technological lines to include space, aeronautics, advanced signals processing, computers, artificial intelligence and the domains of map design, terrain feature extraction, geographic database management and warfighting decisionmaking support. These programs by their complex nature have long lead times from conception to implementation. Decisions must be made now for major programs which are to be operational in the late 1990's and beyond.

I believe America has reached a decision point in designing its current long term strategy. National strategy influences and guides force development and procurement and becomes a significant factor in how we resource security. The perceptions of our potential enemies and those of our allies require the United States to develop an integrated strategy capable of dealing with high and low probability situations of war. The words of Carl von Clausewitz presented in the first chapter of this paper lend credence to deterrence. However in order for deterrence to be effective our ability and will to discriminately use conventional, and, if necessary, nuclear weapons must be clearly understood. Our system calls for budgeting processes which implies limits to ones options. Budgets require us to consider trade-offs in the way we plan and design our forces. It therefore behooves us to develop and procure systems that lend themselves to large payoff gains in their operational capability through low cost product improvement of their critical subsystems.² Multispectral scanners, multi band imagers, and geographic information systems fall within this category.³

I believe that the United States is committed to joint operations involving land and air components from two or more Services. Doctrine calling for deep attack and targeting requires systems which tie the operating forces together through a common thread of information. EEIS and more particularly its multispectral sensor packages can be designed to operate in Army, Navy and Air Force aerial and space platforms and communicate within their systems. What is required is the establishment of an institutional commitment to support an EEIS by our services through their development of improved knowledge data bases designed for the support of a Service yet in a format usable by all. One way of ensuring a unanimity of effort in this arena could be to fence a portion of Service funds in their biennial Program Objective Memorandum (POM) process.

What would be a measure of the criterion from which a satisfactory solution to our strategic and operational levels of military commitment is found? Any solution addressing military support in a region of operation must:

- Provide for an effective defense
- Increase crisis stability
- Not provoke an arms race
- Improve the climate for arms control
- Be acceptable to the public
- Be affordable⁴

I contend that EEIS at the strategic, operational and tactical levels satisfies these criterion. But the operational commander does not have a dedicated EEIS to support him and his subordinate commanders in their decisionmaking ability. The solution to this dilemma is obvious.

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