

AD-A920651

USAWC MILITARY STUDIES PROGRAM

MULTISPECTRAL IMAGERY IN SUPPORT
OF LOW INTENSITY CONFLICT

By

Colonel Michael M. Neer, CM

Colonel Robert F. Hervey
Project Adviser

SDTIC
ELECTE
APR 19 1990
B D

The views expressed in this paper are those of the author and do not necessarily reflect the views of the Department of Defense or any of its agencies. This document may not be released for open publication until it has been cleared by the appropriate military service or government agency.

U.S. Army War College
Carlisle Barracks, Pennsylvania 17013
29 March 1990

UNCLASSIFIED

DISTRIBUTION STATEMENT A: Approved for public release; distribution is unlimited.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) Multispectral Imagery in Support of Low Intensity Conflict		5. TYPE OF REPORT & PERIOD COVERED
7. AUTHOR(s) COL Michael M. Neer		6. PERFORMING ORG. REPORT NUMBER
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Army War College Carlisle Barracks, PA 17013-5050		8. CONTRACT OR GRANT NUMBER(s)
11. CONTROLLING OFFICE NAME AND ADDRESS		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		12. REPORT DATE 1 March 1990
		13. NUMBER OF PAGES 36
		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE
16. DISTRIBUTION STATEMENT (of this Report) Approved for public release; distribution is unlimited.		
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)		
18. SUPPLEMENTARY NOTES		
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The first multispectral imagery space satellite was launched by the United States, on July 23, 1972. This program evolved into the Landsat program that placed five satellites in space. The French, Japanese, and Soviets have followed with programs that parallel Landsat. This paper examines the use of multispectral imagery in military operations, specifically, Low Intensity Conflict. The paper has six objectives. After discussing Low Intensity Conflict doctrinal characteristics, the first objective is to provide an		

DD FORM 1 JAN 73 1473

EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

overview of multispectral imagery technology. Second, the paper broadly examines uses of MSI at the tactical, and theater level. Third, the paper explores the nature of several Low Intensity Conflict activities and provides examples of how MSI can support these operations. Fourth, the paper outlines the procedures for obtaining MSI. In the last chapter, the paper discusses how this data may be integrated into the Corps intelligence system and briefly looks at research developments and space systems planned for the future. The paper should leave the reader with an understanding of MSI technology, exemplify its use in Low Intensity Conflict, and encourage greater integration of MSI in support of military operations.

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE(When Data Entered)

ABSTRACT

AUTHOR: Michael M. Neer, COL, CM

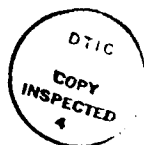
TITLE: Multispectral Imagery in Support of Low Intensity Conflict

FORMAT: Individual Study Project Intended for Publication

DATE: 1 March 1990 Pages: 34 CLASSIFICATION: Unclassified

2- The first multispectral imagery space satellite was launched by the United States on July 23, 1972. This program evolved into the Landsat program that placed five satellites in space. The French, Japanese, and Soviets have followed with programs that parallel Landsat. This paper examines the use of multispectral imagery in military operations, specifically, Low Intensity Conflict. The paper has six objectives. After discussing Low Intensity Conflict doctrinal characteristics, the first objective is to provide an overview of multispectral imagery technology. Second, the paper broadly examines uses of MSI at the tactical, and theater level. Third, the paper explores the nature of several Low Intensity Conflict activities and provides examples of how MSI can support these operations. Fourth, the paper outlines the procedures for obtaining MSI. In the last chapter, the paper discusses how this data may be integrated into the Corps intelligence system and briefly looks at research developments and space systems planned for the future. The paper should leave the reader with an understanding of MSI technology, exemplify its use in Low Intensity Conflict, and encourage greater integration of MSI in support of military operations.

A Multispectral Imagery Technology (MSI) - (250) -



Accession For	
NTIS GRA&I	☒
DTIC TAB	☐
Unannounced	☐
Justification	
By	
Distribution/	
Availability Codes	
Dist	Avail and/or Special
A-1	

INTRODUCTION

Man must rise above the earth - to the top of the atmosphere and beyond - for only then will he fully understand the world in which he lives. Socrates. ca. 450 B.C. ¹

The current world political environment has elevated the importance of Low Intensity Conflict (LIC) operations to support national interests and achieve national military objectives. These operations occur along the continuum between peaceful competition and war and imply the application of military forces to protect vital interests and execute national policy. Military forces employed may be in a violent or non-violent manner and may occur in hostile or friendly environments. Multispectral Imagery (MSI) can provide a wide range of support to enhance the effectiveness of forces employed in a LIC environment. MSI enables the operator and the intelligence analyst to view the world with a perspective made possible only by multispectral scanning systems and the digital analysis of the information they collect.

On July 23, 1972, the United States launched its first Earth Resources Observation Satellite. This satellite, now known as Landsat 1, was the child of more than a decade of labor that was spawned in the 1960's and was catalyzed by the successful launching of the Soviet Sputnik in 1957. Funded by Congress in 1969, it represented the collective effort of over 30 of America's top industrialists. It employed multispectral technology to image the surface of the earth and was considered a success beyond its original expectations.

Since that benchmark, the US has launched Landsats 2 through 5, France has launched SPOT-1, Japan has launched MOS-1, and the Soviet Union claims to have data available from similar remote sensing satellites. These assets have produced hundreds of thousands of images of the earth's surface. Although this represents a wealth of information, little of it has been used in military applications at the strategic, operational or tactical level. Military users complain that MSI products are not readily available when needed, that there is no clear means to acquire them, and that they are not very useable when they are received.² This is largely because the asset does not fit into the normal paradigm of visual and digital intelligence. Furthermore, its false color images and gross resolution have hampered its wide acceptance. However, when understood by commanders and managed by trained analysts, there are abundant opportunities to apply multispectral technology to enhance the effectiveness of military forces employed in a Low Intensity Conflict environment.

This paper will examine the nature of multispectral imagery (MSI) technology and its capabilities. It will also examine the nature of Low Intensity Conflict operations, provide examples of how to use multispectral technology to support these operations, and examine how MSI can be obtained. Finally, it will look at how developmental systems are integrating it into corps operations and discuss future systems. While the paper will provide a discussion of applications, it should not be considered an operator's or leader's comprehensive guide on how to use this asset. Instead, it is intended to provide the reader with a sufficient understanding of the technology with which he can inventively exploit this under-subscribed resource in support of military missions.

LOW INTENSITY CONFLICT

Low Intensity Conflict has been defined as "a politico-military confrontation between contending states or groups below conventional war and above the routine, peaceful competition among states. It frequently involves protracted struggles of competing principles and ideologies. Low Intensity Conflict ranges from subversion to the use of armed force and is waged by a combination of means employing the political, economic, informational, and military instruments of national power. Low Intensity Conflicts are often localized, generally in the Third World, but contain regional and global security implications." ³

Low Intensity Conflict operations are classified into four categories: Insurgency and counterinsurgency; combatting terrorism; peacekeeping operations; and, peacetime contingency operations. Each of these categories has many operational concepts and activities associated with it (Figure 1). While this delineation is not an all inclusive listing of Low Intensity Conflict missions, it serves to illustrate the wide variety of activities that are associated with Low Intensity Conflict.

Outlining the nature of Low Intensity Conflict provides the common reference point that is necessary to explore the application of multispectral support. A similar discussion of multispectral technology will provide an understanding of the science and how it can assist in Low Intensity Conflict operations.

LOW INTENSITY CONFLICT OPERATIONAL CATEGORIES AND ACTIVITIES			
INSURGENCY AND COUNTER- INSURGENCY	COMBATTING TERRORISM	PEACETIME CONTINGENCY OPERATIONS	PEACEKEEPING OPERATIONS
Support to Insurgent Organizations Include: • Psychological Opns • Subversion • Sabotage • Evasion & Escape of Combatants • Intelligence Support • Recruit, Organ, Tng and Log Support • Insertions & Linkups Counterinsurgency Operations Include: • Internal Defense and Development • Civil Military Opns • Security Assistance • Humanitarian or Civic Assistance • Log Support Opns • Populace and Resources Control Operations • Counter Drug Opns • Tactical Operations • Intell Support	Anti-terrorism Counter-terrorism Intelligence Support Physical Security Enhancement Public Affairs Psychological Operations Tactical Operations	Strikes and Raids Show of Force Demonstration Unconventional Warfare Rescue and Recovery Operations Noncombatant Evacuation Operations Support to US Civil Authorities Disaster Relief	Withdrawal and Disengagement POW Exchanges Cease-fire Operations Arms Control Demilitarization and Demobilization Peacemaking

Figure 1. LIC Missions and Activities.

MULTISPECTRAL SENSOR SYSTEMS

The Technology.

Remote sensing is generally described as the process of collecting and interpreting information about a target without being in actual contact with it. It is commonly restricted to methods that employ the detection and interpretation of reflected and generated electromagnetic energy such as heat, light, and radio waves. Excluded are surveys or collection activities that measure electrical, magnetic, and gravitational energy. Conceptually, remote sensing measures and reports reflected energy rather than force fields that would emanate from the latter three. ⁴

Multispectral sensing measures the reflective energy of two or more bands of the electromagnetic spectrum. Electromagnetic energy can be defined as all energy that moves at the speed of light in a harmonic wave pattern. These waves are classified according to their velocity, wavelength, and frequency. The Electromagnetic Spectrum is defined as the continuum of energy that ranges from meters to nanometers in wavelength, travels at the speed of light, and propagates through a vacuum. ⁵ (Figure 2, Upper)

The earth's atmosphere absorbs and scatters energy in the gamma-ray, x-ray, and most of the ultraviolet regions of the spectrum. Since remote sensors measure reflected energy, space based sensors do not attempt detection in these regions. Most generally,

these sensors are designed to detect energy in the microwave, infrared, visible, and long-wavelength bands of the ultraviolet regions of the spectrum. ⁶ (Figure 2, Lower.)

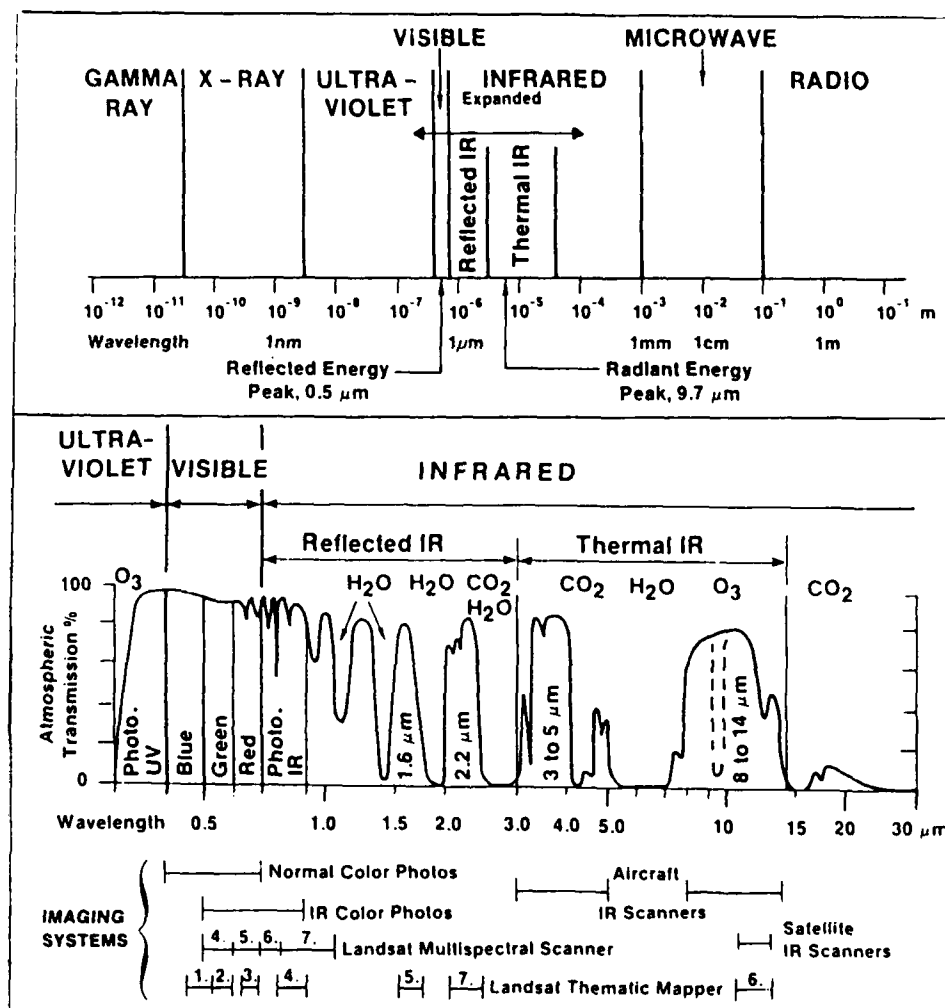


Figure 2. Electromagnetic spectrum (upper) and expanded diagram of the visible and infrared regions (lower). ⁷

The most significant difference between a human eye and a remote sensor is that the human eye detects reflected energy only in the visible region of the spectrum. Furthermore, when the eye detects this energy, it sees the entire visible region simultaneously. Multispectral sensors acquire data in more narrow spectral bands and collect information in regions of the spectrum that the eye and traditional framing and scanning systems are incapable of detecting. (Figure 2, Lower) For example, the

diverse characteristics of bodies of water can be observed in the green band of the visual region. Sediment plumes, shoals and reefs in shallow water become visible, as well as the water's turbidity. This allows analysts to study turbidity patterns, water currents, sediment movement, and shallow water for navigation channels and hazards. Red band data highlights man-made features such as roads, buildings, towns, farms, and bridges. Other bands can measure land use changes and allow distinction between various types of vegetation and foliage. Others discriminate land from water and offer better penetration of haze. ⁸

Multispectral sensors measure reflected energy, usually sunlight. Sunlight reflected from the earth to the collector is separated into distinct wavelengths by a spectrometer then fed into an array of detectors. Each detector measures the radiant energy which is transmitted to earth stations as electronic image data. Detection has been limited to the reflected infrared, thermal infrared, and the visible regions of the spectrum between 0.45 to 0.69 micrometers (μm). Images in the blue region have not been collected because the signal to noise ratio characteristics associated with multispectral scanners and the scattering effects of the atmosphere limit the dependability of data collected in this region. ⁹

Landsats 1 through 3 employed multispectral scanning systems that detected in four band regions. Landsats 4 and 5 employed an improved system called a Thematic Mapper (TM). The TM improved the spatial resolution and expanded the number of bands. (Figure 2, lower). The overall technological quality of the platform was also improved. The various bands of multispectral scanning and thematic mapper spectral systems, the wavelength of the detected bands, the color associated with the bands and the characteristics of the data acquired are disclosed at figure 3.

Multispectral Scanner Bands ¹⁰			
Band	Wavelength (μm)	Color	Characteristics
4	0.5 - 0.6	Green	Characteristics of bodies of water can be observed. Sediment plumes, shoals and reefs in shallow water are visible, as well as the turbidity of water.
5	0.6 - 0.7	Red	Highlights man-made features such as roads, buildings, towns, farms, bridges, etc.
6	0.7 - 0.8	Reflected IR	Land use changes and distinctions between various types of vegetation and foliage.
7	0.8 - 1.1	Reflected IR	Distinction between land and water. Offers the best penetration of haze.
Thematic Mapper Spectral Bands ¹¹			
Band	Wavelength (μm)	Color	Characteristics
1	0.45 - 0.52	Blue-green	No MSS equivalent. Maximum penetration of water which is useful for bathymetric mapping in shallow water. Useful for distinguishing soil from vegetation and deciduous from coniferous plants
2	.052 - 0.60	Green	Coincident with MSS Band 4. Matches green reflectance peak of vegetation, which is useful for assessing plant vigor.
3	0.63 - 0.69	Red	Coincident with MSS band 5. Matches a chlorophyll absorption band that is important for discriminating vegetation types.
4	0.76 - 0.90	Reflected IR	Coincident with portions of MSS bands 6 and 7. Useful for determining biomass content and for mapping shorelines.
5	1.55 - 1.75	Reflected IR	Indicates moisture content of soil and vegetation. Penetrates thin clouds. Good contrast between vegetation types.
6	10.40 - 12.50	Thermal IR	Nighttime images are useful for thermal mapping and for estimating soil moisture.
7	2.08 - 2.35	Reflected IR	Coincides with an absorption band caused by hydroxyl ions in minerals. Ratios of bands 5 and 7 are potentially useful for mapping hydrothermally altered rocks associated with mineral deposits.

Figure 3. Spectral band characteristics.

MULTISPECTRAL IMAGERY (MSI) SPACE SYSTEMS

Multispectral Imagery (MSI) satellites are placed into near polar, sun-synchronous orbits. Each orbit occurs at the same relative sun time which allows accurate comparison of image scenes. The platforms are usually in a near polar orbit to allow nearly full coverage of the earth. The global coverage period, the time required to map the entire earth, varies with the satellite's orbital characteristics, the scan angle of the detection system, and the width of the sensor's field of view.¹² The near polar orbit and the collector's constant scanning angle causes overlapping differentials between polar and equatorial scenes. With Landsat systems, polar scene overlapping allows repeated scanning as often as every 7 days; equatorial scenes, however, can be recorded only every 18 days. Different temporal cycles apply for other platforms such as SPOT and MOS-1. (Figure 4)

CHARACTERISTICS OF MULTISPECTRAL SENSOR SYSTEMS ^{13 14}				
SENSOR SYSTEM	BAND WIDTH (nm)	NUMBER OF BANDS	SPATIAL RESOLUTION (meters)	Temporal Nadir Cycle (Days)
Landsat-5 (US) Multispectral Thermal Mapper	100-300	4	80	16
	60-140	7	30	
SPOT (France, Belgium, Sweden) Multispectral Panchromatic	80-420	3	20	26
		1	10	
Marine Observation Satellite (MOS-1) (Jap)		4	45	
AVIRIS ¹⁵	10	220	10	

Figure 4. Multispectral system characteristics.

Landsat. The United States has launched five space based multispectral imagery platforms. These satellites, Landsats 1 through 5, were all launched into sun-synchronous, near polar orbits at altitudes of 705 km or 919 km. These systems collect data in a perfect nadir perspective; nadir refers to the point on the earth that is intersected by a line from the sensor and the center of the earth. Of the five Landsats launched, only Landsat 5 is still operational.

SPOT. SPOT is a combined effort of France, Belgium, and Sweden. It is in a sun-synchronous, near polar orbit at an altitude of 832 km. It acquires data in two modes, multispectral and panchromatic. SPOT has improved resolution over the Landsat, but, the increased resolution reduces the scan angle and increase the temporal nadir cycle (or equatorial revisit time) to 26 days. Its most significant advantage is its ability to rotate the satellite's collection system to produce off-nadir images. This increases the number of scene visits the system can make during each temporal nadir cycle and allows the creation of image pairs. During its 26 day cycle, SPOT can produce 7 equatorial off-nadir image pairs. Stereo images provide exceptional depth perception that is absent in nadir imaging. ¹⁶

MOS-1. The Japanese Marine Observation Satellite (MOS) carries three sensors on board. The MSI sensor provides 45 meter resolution, the visible/thermal infrared sensor provides 90 meter resolution and the microwave scanner provides 30 meter resolution. ¹⁷

APPLYING MULTISPECTRAL TECHNOLOGY TO MILITARY REQUIREMENTS

The periodic nature of multispectral sensor platforms in near polar orbit restricts the ability of the system to provide current data on demand. Since its responsiveness will vary greatly, for planning purposes new data should not be expected in less than the maximum temporal nadir cycle of the satellite plus processing time. High priority missions for new data may require as long as 30 to 45 days. This does not diminish the effectiveness of MSS technology; it means that multispectral data is optimally applied to accomplish many of the abundant non time sensitive requirements in support of military operations.

The use of military forces in a LIC environment may imply their employment in a non-lethal activity such as internal defense and development, civil military operations, disaster relief, and support to civil authorities. However, the very nature of a military force, its organization, training, and equipment, suggests employment using its more lethal characteristics. They are most likely to be employed in a more tactically direct action such as direct assistance, strikes, raids, counter terrorism, and rescue and recovery operations or a deterrent mode such as show of force, peacemaking, and cease-fire operations. Conventional forces employed in a LIC mission may find their environment as hostile and lethal as in a mid or high intensity environment. Tactics employed by the forces may not vary from those employed on a higher intensity battlefield. At the direct action level, LIC may be nothing more than an abstract concept. Therefore, a general discussion of overall tactical and theater applications of Multispectral Imagery will be explored to provide a foundation from which more specific discussions in a LIC environment can evolve.

Traditionally, multispectral data has been used to accomplish peaceful and commercial socio-economical functions. The chart at Figure 5 provides a snapshot of the traditional applications of MSI for commercial requirements.^{18 19} Few of these read as uses the military operator will find beneficial in conducting military operations and missions. Figure 6, transforms the commercial applications of multispectral data into more specific military applications. This initial focus broadly covers applications for tactical, campaign/theater, and national purposes. This examination will provide a useful understanding of common direct action missions that span the continuum from Low Intensity through High Intensity Conflict. Following this will be a more definitive examination of specific LIC missions and activities that includes both the hostile combat environment and the more peaceful applications of military power, the other side of LIC.

Tactical Applications. Operators at the tactical level must develop an in-depth knowledge of the battlefield. The better their understanding of the terrain, the better is the probability of success. This process is a continuous activity that builds a data base of information about the enemy, the weather, and the terrain. Multispectral data can be an indispensable tool among the array of intelligence collectors available to accomplish this intelligence mission. It can be used to produce maps where none exist. It can identify mobility corridors for rapid movement and conversely identify likely avenues for enemy approaches, choke points, and potential barrier locations for defensive operations. Coupled with weather data it can help predict terrain where mobility will be enhanced or inhibited by inclement conditions.

FIGURE 5, TRADITIONAL APPLICATIONS OF MULTISPECTRAL DATA 18 19

Land Use and Mapping	Oceanography and Marine Resources	Water Resources	Agriculture, Range and Forestry Resources	Geology	Environment
• Classification of land uses. • Cartographic mapping. • Categorization of and map updating. • Land capability. • Separation of urban and rural lands. • Regional planning • Mapping of transportation networks. • Mapping of land/water boundaries. • Mapping of wetlands. • Identify floodplains. • Identify subsurface coal fires.	• Detection of living marine organisms. • Determination of turbidity patterns and circulation. • Mapping shoreline changes. • Mapping of shoals and shallow areas. • Studies of eddies and waves. • Mapping Oceanic circulation patterns.	• Determination of water boundaries and surface water area. • Mapping of floods and flood plains. • Determination of areal extent of snow boundaries • Measurement of glacial features • Measurement of sediment and turbidity patterns. • Determination of water depth. • Delineation of irrigated fields. • Inventory of lakes. • Sea & ice mapping.	• Identification of Crops • Timber Range • Measurement of timber acreage. • Measurement of crop acreage. • Determination of range readiness and biomass. • Determination of vegetation vigor and/or stress. • Determination of soil condition and assn. reforms. • Assessment of grass and forest fire damage.	• Recognition of rock types. • Mapping major geologic units. • Revising geologic maps. • Delineation of unconsolidated rock and soils. • Mapping igneous intrusions • Mapping recent volcanic surface deposits. • Mapping land reforms. • Identification of mineral zones. • Determination of regional structures. • Mapping linears (fractures). • Mineral, uranium oil, and geothermal energy exploration. • Project earthquake, and landslide hazards.	• Monitoring surface mining and reclamation. • Mapping and monitoring of water pollution. • Detection of air pollution and effects. • Monitoring environmental pollution.

MILITARY APPLICATIONS OF MULTISPECTRAL DATA		
TACTICAL LEVEL APPLICATIONS	CAMPAIGN/OPERATIONAL LEVEL APPLICATIONS	NATIONAL
• Intelligence preparation of the battlefield. • Create current maps • Terrain evaluation. • Identification of mobility corridors. • Determine soil trafficability. • Terrain evaluation for ingress and egress operations. • Integrate with DMA digital data to create 3-dimensional perspective viewing. • Dropzone and landing zone evaluation. • Evaluation of cover and concealment. • Identify potential water sources. • Identification of potential minefields. • Identify maneuver damage.	• Intelligence preparation of the battlefield. • Evaluation and identification of lines of communication. • Evaluation of potential port sites. • Identification and analysis of potential airfields. • Evaluation of amphibious landing sites: - Bathymetric mapping - Identification of underwater obstacles. - Slope, depth, and bottom characteristics. - Current identification. - Trafficability of landing site terrain • Identification of mineral resource sites. • Seasonal terrain change analysis. • Identify vegetation patterns and density. • Identification of shipping lanes • Defensive and offensive mobility corridors.	• Change analysis. • Confidence and security building measures. • Treaty compliance and arms control verification.

Figure 6

Stereo scenes, when integrated with other digital mapping data, provide dimensional viewing of the target area prior to the insertion of special operations personnel or the conduct of air special operations and interdiction missions. It can help map routes of ingress and egress for special operations personnel and identify routes where they will

likely encounter maximum cover and concealment, natural obstacles, sources of water, and man-made facilities.

Multispectral data can also identify unexpected soil disturbances. With this, the operator is provided with a warning that may justify caution or more detailed analysis. This may help identify areas that have been disturbed in the creation of minefields, roadways, trails, or provide pictorial evidence for exercise maneuver damage claims.

The performance of detailed terrain analysis reduces the number of uncertainties that may affect the essence of the operation. The nature of terrain is an immutable element of the battlefield. The understanding of vegetation, surface materials, surface drainage, relief, obstacles, lines of communication, ground and surface water, and mobility corridors or impediments can arm the commander with a knowledge that can multiply the effectiveness of his forces in the offense and strengthen his defenses. Multispectral data support can assist in compiling this information.

Campaign/Theater Applications. Operational art involves fundamental decisions about how and where to fight. Its essence is the identification of the enemy's center of gravity and in being able to concentrate the requisite combat power at that point to achieve success. It requires a broad vision that will drive campaign and theater planning. Data provided through multispectral analysis can assist the commander and his staff in planning at the theater/operational level. It can be a complementary tool in preparing an intelligence estimate of the theater. It can assist in identifying mobility corridors for the movement of forces and the supporting logistical trains. It can be used to conduct evaluations of potential sites for amphibious landings, and assist in identifying mobility obstacles to rapid movement beyond a beachhead. It can assist in understanding how vegetation, mobility capacities of terrain, and the effects of weather

will enhance or impede allied and opposing forces operations. Coupled with existing Defense Mapping Agency digital mapping data, it can provide maps of the theater that indicate the most current urban and terrain changes. This includes changes in urbanization, roads, railroads, and waterways. Multispectral imagery support can add depth to the broad vision necessary for campaign success. While it will not identify the center of gravity it may assist in developing the operational concept that will successfully attack it.

National Applications. The gross resolution of current space based multispectral systems limits its effectiveness at the national level. However, as a complement to other intelligence systems, MSI can provide the analyst with a tool that eases the task of identifying a wide range of surface and subsurface alterations to include new construction, crop changes, the elimination of forested lands, changes in wetlands and waterways, new roads and railroads, or other essential elements of information required by intelligence analysts. MSI platforms' recurrent cycles and their near full earth coverage provide the analyst a gross filter to help identify possible intelligence targets for more detailed collection and analysis activities.

Low Intensity Conflict. Having developed a baseline that exposes the varied capabilities of multispectral imagery, a more specific examination of Low Intensity Conflict applications can be accomplished. A complete discussion of all of the LIC activities will not be performed. Instead, selected activities will be explored to exemplify possible applications in support of these missions. Figure 7, Low Intensity Conflict Applications of Multispectral Data, outlines by category some of the opportunities to apply MSI support to these operations.

Insurgencies. An insurgency is an organized, armed political struggle whose objective is to secure political power by replacing an existing government through revolutionary action. It may, though, have more limited objectives, such as securing a different political processes for the populace, the recognition of a political party, changes in economic practices, or achieve human rights concessions. These goals may be accomplished through hostile revolutionary activities or through less violent means. Insurgencies usually follow revolutionary doctrine and use armed military or paramilitary forces as an instrument of policy. An insurgency is dependent upon incipient internal conditions to thrive and expand. As such, it needs no external support to succeed; however, external support can advance the insurgency to an earlier and successful culmination. There are four types of external support: Moral (acknowledgement and legitimacy); Political (promotion of the insurgents cause in international forums); Resources (money, weapons, food, advisors, training, and intelligence); and, Sanctuary (a secure habitat for training and logistical bases). When directed, U.S. forces can provide the following types of assistance: recruitment, organization, training and equipping forces to perform military operations (usually in the form of unconventional or guerrilla warfare); psychological operations; infrastructure development; intelligence support; surreptitious insertions and extractions of personnel; linkups; evasion and escape mechanisms and networks for combatants and other personnel; subversion and sabotage; and, logistical support.²⁰

When U.S. forces are employed in support of insurgents, they accomplish many of the same mission planning considerations as conventional combatants. A critical and accurate terrain assessment of the operational area is essential to conducting successful operations. Multispectral Imagery can help accomplish this requirement. Combined

APPLICATIONS OF MULTISPECTRAL IMAGERY IN LOW INTENSITY CONFLICT			
INSURGENCY AND COUNTER- INSURGENCY	COMBATting TERRORISM	PEACETIME CONTINGENCY OPERATIONS	PEACEKEEPING OPERATIONS
• Intelligence preparation of the battlefield. • Create current maps • Terrain evaluation for ingress and egress operations. • Dropzone and landing zone evaluation. • Evaluation of cover and concealment. • IDAD - Traditional applications of MSS data. - Development of: - Roadways. - Port facilities - Airfields - Navigable river routes - Identification of water sources. - Agricultural development. - Urban development. - Regional planning. - Mineral identification and exploitation. • Tactical Opns: See Column Mil Applications	• Integrate with DMA digital data to create 3-dimensional perspective viewing. • Dropzone and landing zone evaluation. • Terrain evaluation for ingress and egress operations. • Intelligence preparation of the battlefield. • Create current maps • Terrain evaluation.	• Intelligence preparation of the battlefield. • Terrain evaluation for ingress and egress operations. • Integrate with DMA digital data to create 3-dimensional perspective viewing. • Dropzone and landing zone evaluation. • Identification of evacuation locations • Evaluation of cover and concealment. • Create current maps • Terrain evaluation for ingress and egress operations. • Tactical Opns: See Column Mil Applications	• Change analysis. • Confidence and security building measures. • Treaty compliance and arms control verification. - Construction of new production facilities - Creation of de-militarized zones and border zones

Figure 7. LIC applications of Multispectral Imagery.

with other DMA digital data, accurate and current relief maps can be produced. MSI can identify mobility corridors that offer cover and concealment to the forces employed in paramilitary operations. It can identify water hazards, wetlands, and marshes that will

affect operations in the area. Dropzones and landing zones can be identified to facilitate logistical re-supply operations and surreptitious insertions and extractions. A secure and concealed base camp for combatants is critical to the survival of the insurgent force. Conducting a digital analysis of MSI data, foliage, trafficability, and relief analysis can produce potential basecamping sites that offer cover, concealment, and mobility characteristics that are beneficial to operations. Furthermore, MSI can assist in identifying ingress and egress routes that will facilitate rapid and safe evasion and escape routes for the deployed force, and members of the insurgent combatant and political leadership as necessary. This type of analysis might include the identification of foliage, relief, water masses, marshlands, and glacial/snow coverage that could enhance or impede evasion and escape.

Counterinsurgency. Counterinsurgency includes all of those actions taken by a government to defeat an insurgency. A counterinsurgent must understand that the chief threat to his government lies in the insurgent's political and popular support, not from the use of military force. Any campaign that does not redress the political claims and demands of the insurgents will not achieve lasting success. Combat operations may be essential to offer neutralization of the opposing force until the basal issues are rectified. A counterinsurgency embraces the four interdependent functions of Internal Defense and Development. They are: Balanced Development (political, social, and economic reform programs); Security (security of the populace, government, and the country's resources); Neutralization (the physical and psychological separation of the insurgents from the population- this may involve exposure, arrest and prosecution, or combat action); and, Mobilization (organized manpower and materiel resources to motivate and organize popular support of the government). U.S forces are generally not employed in combat roles in counterinsurgency operations. Their use in combat, while not precluded, should be considered an exceptional occurrence. U.S forces will chiefly

provide the following support: Intelligence support; combined operations; civil-military operations (includes civil affairs and psychological operations); humanitarian or civic assistance; logistical support; populace and resources control operations; drug interdiction operations; and tactical combat operations. ²¹

Multispectral Imagery can support a wide variety of counterinsurgency missions. The same detailed terrain analysis used in support of insurgents can be similarly beneficial to the counterinsurgent. Using detailed MSI terrain analysis, the counterinsurgents may gain an understanding of where insurgent base camps may be located, and probable corridors and sites for infiltration, exfiltration, or logistics re-supply operations. Additionally, by using digital change analysis, intelligence analysts may be able to detect evolving trail networks, and re-supply routes. Since the reflective energy of various foliages produce distinct signatures, MSI can be used to identify very specific crops and other ground cover. Such analysis can assist in locating drug crops or other agricultural products that support insurgents. These intelligence missions along with the compliment of applications to support combat operations previously discussed, can be provided to the host nation military or paramilitary forces in neutralization missions or may be used in support of U.S forces should they be employed in a direct combat role.

The chief goal of the military in nation building is the conduct of counterinsurgency operations. While most of the functions of nation building are the responsibility of the Ambassador and the country team, military assistance teams invariably become significantly involved in developing and executing a full range of reform programs. MSI can assist in accomplishing a wide range of requirements to include: land use and mapping; oceanographic mapping and marine resource applications; water management; agriculture, range and forestry programs; and, geological resource identification. The

full spectrum of traditional applications (Figure 5) can be very useful in nation building missions. The type of MSI support will vary with the nature of the reform required. To aid in agricultural reforms, MSI could be used to identify arable land, water and flood management requirements, and to assist in mapping requirements for regional planning. MSI can abet efforts to inventory and type classify forests, measure crop acreage, and determine soil conditions of arable lands. Roads, rail lines, waterways, airports and seaports often must be developed or expanded. MSI can help identify the best corridors for road and railroad networks and locate rock deposits to build roadbeds and develop these facilities. MSI can also be used to identify potential deposits of mineral zones, uranium, oil deposits, and potential geothermal energy sources. The use of MSI to accomplish these tasks will assist host nation and U.S. forces in complementing campaigns for the balanced development of the nations economic reforms and the mobilization of its resources to redress the deficiencies upon which an insurgency thrives.

Combatting Terrorism. Terror can be created through the use of a hostile and violent act or the belief that such an act will be used. The Department of Defense defines it as "the unlawful use of -- or threat of -- force or violence against people or property to coerce or intimidate governments or societies, often to achieve political, religious, or ideological objectives." ²² Terrorists acts can be performed by criminals, mentally disturbed or incapacitated individuals, or politically motivated organizations. In the latter case, the organization may or may not be state supported. Terrorists usually are motivated by one or more of five objectives: Recognition (national or international recognition of a cause); Coercion (an attempt to force behavior though specialized targeting of facilities or individuals with threats of destruction or death); Intimidation (the opposite of coercion, it attempts to prevent actions by groups or individuals); Provocation (actions taken with the goal to elicit overt reaction in an attempt to create

public sympathy or support); and, Insurgency Support (any or all of the preceding objectives to support insurgencies). Terrorists use a variety of methods to accomplish their objectives. Included in these are assassination, arson, bombing, hostage-taking, hijacking, kidnaping, raids, seizure, sabotage, hoaxes, or the use of chemical-biological weapons. U.S. forces respond to this threat through anti-terrorism and counter-terrorism operations. Anti-terrorism actions are those passive measures taken to reduce the exposure or vulnerability to terrorist acts. Counter-terrorism operations include the full spectrum of overt measures taken to deter, prevent, or respond to terrorism. These actions, whether reactive or preemptive, take on the characteristics of strikes or raids. ²³

Counter-terrorism measures lend themselves to support by MSI, particularly those planning actions in preparation for strikes or raids. MSI when combined with DMA digital data can create three-dimensional perspectives of target area encampments, urban areas, and the routes for ingress and egress. Such dimensional viewing allows air or ground crews the opportunity to preview the area of operations prior to the actual conduct of the strike or raid. Where ground forces will be surreptitiously inserted and extracted, MSI can be used to evaluate potential airfields or dropzones for their use. To facilitate ground movement, MSI terrain analysis can be used to identify the best routes for infiltration into and out of the operational target that will offer the best cover, concealment, and identify relief, water, natural and man-made obstacles that may enhance or diminish a successful covert movement.

Peacetime Contingency Operations. Peacetime contingency operations are characterized by short-term employment of military forces in potentially hostile environments. These operations are politically sensitive, emanating from crisis management or crisis avoidance situations, and may be conducted abroad or domestically.

These operations include but are not limited to: Strikes and raids; show of force demonstrations; disaster relief; noncombatant evacuation operations; rescue and recovery operations; peacemaking; unconventional warfare; security assistance surges; and, support to US civil authorities. A single mission, rescue and recovery operations will be discussed.

Rescue and recovery operations. Rescue and recovery missions are usually conducted to extricate U.S. or friendly foreign national citizens or the location, identification, and recovery of equipment or materials critical to national security. These missions are very sensitive and require precision planning, support, and timing in their execution. They may be covert, executed by specially trained special operations personnel, or may be overt, employing special operations forces complemented and supported by conventional forces. In all cases, their success depends on stealth, security, accurate and timely intelligence, deception, and rapid execution and conclusion.²⁴ Detailed planning and the timing of force employment are critical in executing these missions. Detailed terrain analysis using MSI could identify dropzones, landing zones, and natural or mobility obstacles that could affect the timely concentration of combat power to overwhelm opposing forces. This same terrain analysis could identify concealment and cover to expedite the safe and effective employment of forces. Many operations may be conducted where no land maps exist. Such a case existed in operation Urgent Fury when U.S. forces were deployed to Grenada in October 1983. MSI can supply current relief maps to plan the employment and facilitate coordinated and accurate maneuver of ground forces.

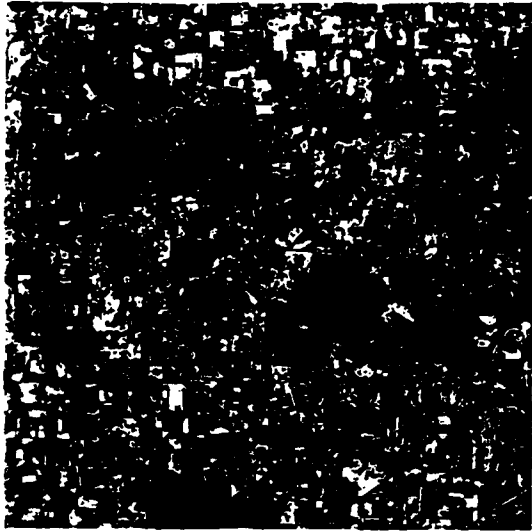
Arms Control. Multispectral Imagery can be used as an adjunct to other intelligence collectors to assist in monitoring compliance with arms control treaties. Its broad and worldwide periodic coverage makes it an exceptional technical means to perform digital

change analysis. MSI data is archived and manipulated in digital format. Digital analysis of historical scenes compared with current imagery can provide initial indications of potential noncompliance with treaty requirements. Reflective changes can be highlighted through digital comparison to identify targets for detailed review by analysts using more sophisticated assets. An example of this process is demonstrated in the thermatic mapper change detection photographs shown in figure 8.²⁵ In this example, a digital analysis of the false color composite scene taken in 1986 was compared with the same scene taken in 1982. A multispectral change magnitude image was produced that identified the changes that occurred between the scenes. The changes were then identified in red. The nearly complete surface coverage of the earth and continuously acquired data provide the analyst with a superb gross filter to identify new manufacturing facilities, military construction and facility expansion, missile launch sites, anti-ballistic missile networks and ABM radar sites, road networks for mobile missile systems, or other intelligence targets that can be identified by changes in reflected energy.

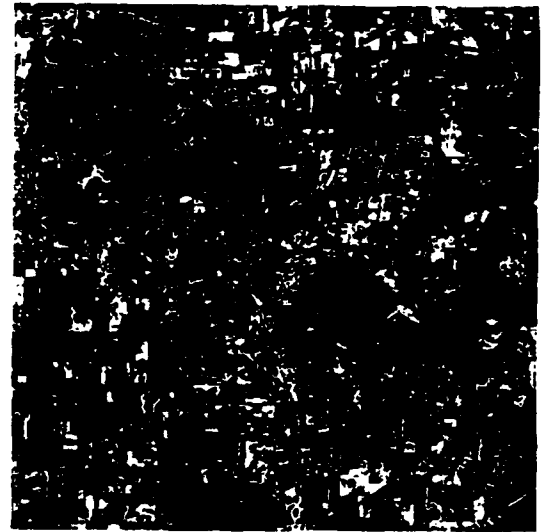
The concepts discussed above are only a framework from which greater and more resourceful applications of multispectral imagery can emerge. Analysts will learn new and more innovative methods to manipulate this digital data through proper training and use in current operations. Whether used alone or integrated with other sources, it has great potential to enhance the intelligence provided in support of the full spectrum of Low Intensity Conflict activities and missions.

figure 8

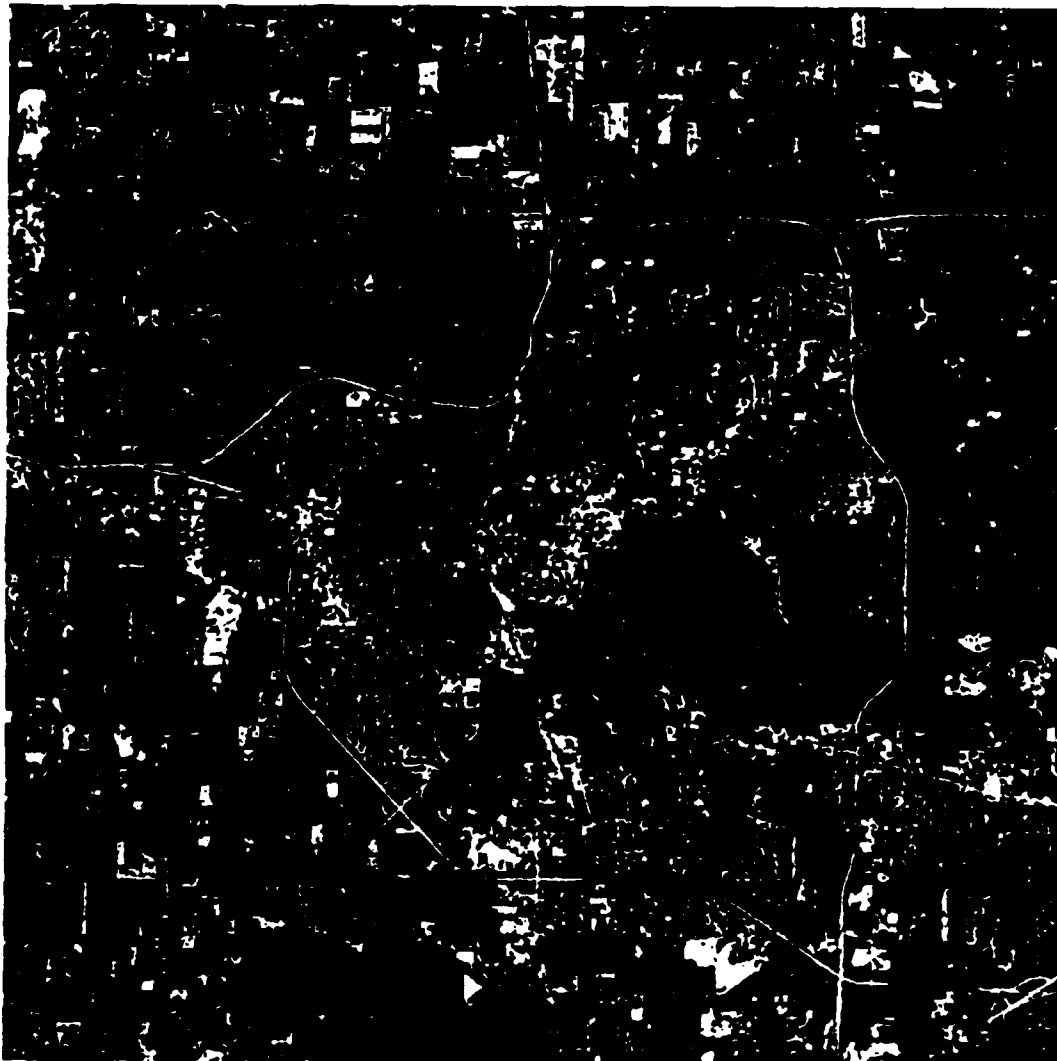
**THEMATIC MAPPER CHANGE DETECTION
ANN ARBOR, MICHIGAN**



1982 FALSE COLOR COMPOSITE



1986 FALSE COLOR COMPOSITE



MULTISPECTRAL CHANGE MAGNITUDE IMAGE

OBTAINING MULTISPECTRAL IMAGERY SUPPORT

Collectively, civil systems offer a variety of capabilities. Until recently, the acquisition of this data has been difficult and ill-defined. In May 1989, the Director, US Geological Survey (USGS), the Deputy Chief of Staff for Intelligence, US Army, and the Chief of Engineers, US Army, entered into a memorandum of agreement to facilitate the acquisition of this data. This cooperative effort will provide savings to the government through the sharing of scientific expertise, capabilities, and the exchange of analytical capabilities. ²⁶

Under the agreement, the USGS provides technical support to designated US Army purchaser groups. As part of the technical support, the USGS is the primary purchasing agent of civil MSI data and services for the Army. They provide requesting user groups with data and products from Landsat, SPOT, and other current and future domestic and foreign satellite systems during periods of peace, crisis, and war. Under the agreement, emergency requests for USGS and archived products and services are processed and shipped within 24-48 hours. Emergency requests for non-Landsat data and services are forwarded to the appropriate vendors within 3 hours of the request. The delivery time for non-Landsat services is negotiated by the USGS at the time services are ordered from the vendors. ²⁷

To acquire these services, user groups must establish an account with the USGS Earth Resource Observation System Data Center (EDC), Sioux Falls, South Dakota. Users pay for services at the established price outlined in the USGS contract with the

vendors. The user establishes an account with the EDC through a separate service memorandum and pays for services using Standard Form 1080 through the servicing Finance and Accounting Office identified in the service memo.²⁸ User groups are identified as:

1. Office of the Secretary of the Army and subordinate offices.
2. Office of the Chief of Staff of the Army and subordinate staff.
3. Army Intelligence Agency and subordinate operating agencies.
4. Training and Doctrine Command and subordinate centers and schools.
5. US Army Materiel Command.
6. Forces Command.
7. Intelligence and Security Command.
8. US Army Europe.
9. US Army South.
10. US Army Western Command.
11. US Army Japan.
12. Eighth US Army.
13. Army Special Operations Command.
14. US Army Corps of Engineers.
15. US Army Strategic Defense Command.
16. Health Services Command.
17. Criminal Investigation Command.
18. Military Traffic Management Command.
19. Information Systems Command.
20. Military District of Washington.

TRANSITIONING FROM THE PRESENT TO THE FUTURE

The future holds much promise for technologically enhanced multispectral systems and capabilities. Current systems will be made increasingly available at the tactical and operational levels. The hardware and software to receive, manage, analyze, and distribute the data will make this technology one of the most useful sources of visual and digital intelligence.

Continual improvements in tactical and operational exploitation systems are being made at the corps and divisional levels. The XVIII Airborne Corps currently uses and provides MSI support to subordinate commands. MSI digital data is acquired by the Remote Viewing Station (RVS) at Fort Bragg, where it is archived for future use and analysis. As required, prints of the imagery are made available throughout the Corps via normal hardcopy distribution. Alternatively, prints can be transmitted electronically from the Imagery Readiness Facility (IRF) to deployed Tactical High Mobility Terminals (THMT). Softcopy data provided to the Remote Viewing Stations (RVS) is also forwarded to the 30th Engineer Battalion (Topographic); that data is used to create pictographic maps for hardcopy distribution. A schematic of this network is shown at figure 9. The XVIII Airborne Corps is planning to expand this capability to incorporate all of the divisions within the Corps.²⁹ The natural progression of this is the standardization and expansion of this or similar capabilities to all Army corps.

IMAGERY DISSEMINATION NETWORK (PRE-DEPLOYMENT PHASE)

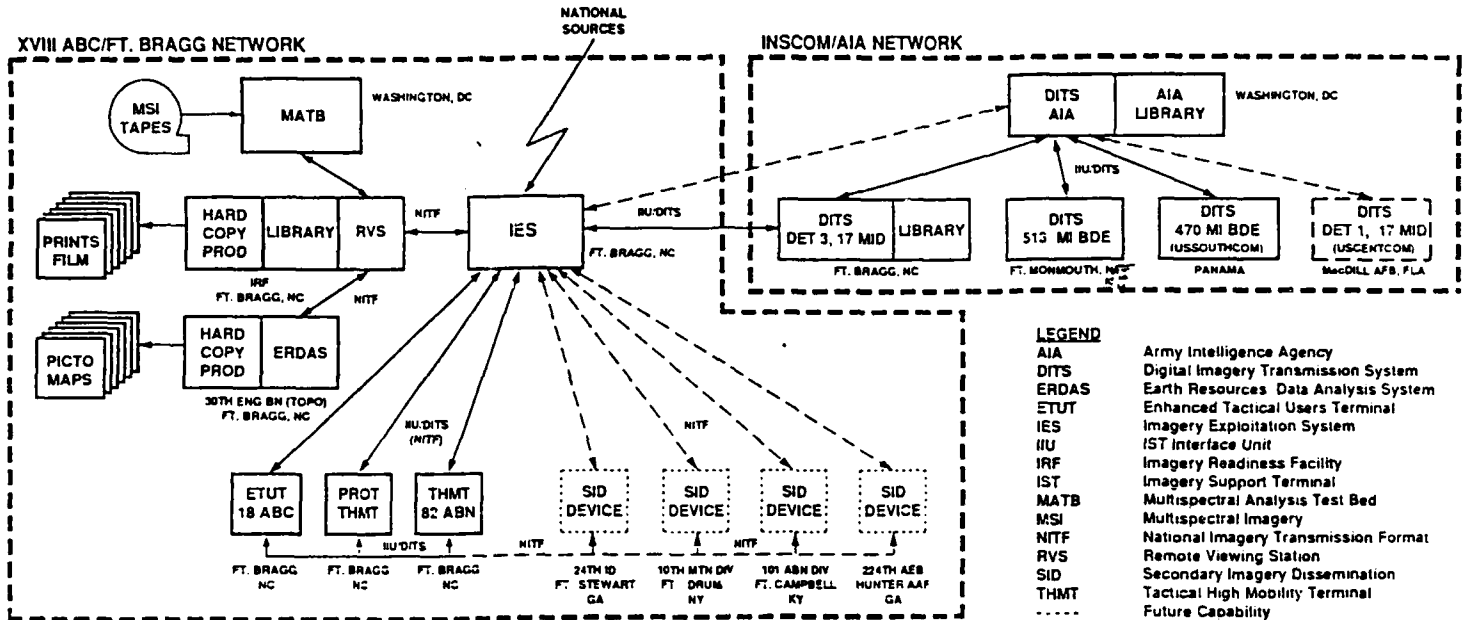


Figure 9. Imagery Dissemination Network, XVIII Airborne Corps, Ft Bragg, NC. 30

New spacebased sensor systems will provide enhanced and expanded capabilities. Landsats 6 and 7 are planned for the mid 1990's. Landsat 6 will provide significantly improved capabilities over previous systems. Using an Enhanced Thematic Mapper (ETM), it will provide six bands in the visible, near infrared, and shortwave infrared regions with a 30 meter resolution, and one panchromatic visible band with 15 meter resolution. It will also have a multispectral thermal infrared (TIR) system that will provide one midwave infrared band with 120 meter resolution and four longwave bands with 60 meter resolution. Its third onboard system will be the Compact Wide-Field Sensor (CWIFS) providing wide swath, rapid revisit capabilities for ocean and coastal data. Landsat 7 will employ the Landsat 6 complement of sensors to provide continuity.

It will also carry an Advanced Landsat Sensor (ALS) for high resolution custom data. This system will provide a 48 km swath width and cross track pointing for rapid access of priority targets. Some of the systems may provide resolution as fine as three meters.³¹

There are a host of foreign commercial systems awaiting deployment. The French-Belgium-Sweden consortium plans to deploy SPOT 2, 3, 4, and 5 over the next ten years. SPOT 2 is fully developed and will be launched when economics support the additional system. The Japanese will launch MOS-2 depending upon the success of MOS-1. Canada has developed a Synthetic Aperture Radar System that is planned for deployment in the 1990's. Lastly, the European Space Agency plans to launch ERS-1 in the 1990's. The ERS-1 will employ multispectral imagery and microwave technology.³² These foreign systems will provide a competitive compliment to domestic systems that will encourage even further improvements in resolution and capabilities.

The most revolutionary multispectral developments will come in hyperspectral imagery (HSI) systems. The developmental Airborne Visible Infrared Imaging Spectrometer (AVIRIS) is an example of this technology. Rather than limiting scanning bands to only 3 or 4, HSI technology provides tens of bandpass images. The AVIRIS provides 220 bands of imagery. As technology incorporates the full continuum of the spectral region of the electromagnetic spectrum, more comprehensive spectrographic analysis will be made available to the information consumer. The spectrographic signature of individual reflective surfaces will enable the analyst to identify nearly anything within the spatial resolution capabilities of the sensing system. Woodland camouflage covering that may not be detectable by the naked eye will be ineffective against HSI technology. If the spectrographic signature of a specific uniform is known and the resolution of the system is great enough, a soldier wearing that uniform, if not

covered from view, may not escape HSI detection.³³ This and similar emerging technologies and their applications are now on the horizon.

The most significant challenge that faces the operational community is planning now to acquire these technologies and integrate them into operational missions.

CONCLUSION.

Multispectral imagery is not without its limitations. It cannot see through cloud cover. It currently has a limited resolution capability. Its near polar orbit imposes lengthy temporal cycles to accomplish full earth coverage. Data may often be at least several days aged before it is available to the analyst. Nonetheless, it can still provide a wealth of information not available through any other means. Applying this technology to non-time sensitive imagery and information requirements of Low Intensity Conflict operations can significantly enhance the effectiveness of diminishing resources. The non-traditional images provided by multispectral technology demand that analysts and users understand how the data is collected and how to interpret the end products. When used by skilled operators, multispectral imagery can become a powerful resource at the national, operational and tactical level.

Improvements in the spatial resolution will occur as future systems are launched. Landsats 6 and 7 will provide significantly improved hardware capabilities. User software and hardware are becoming integrated into the intelligence information systems at operational and tactical levels. The softcopy data from operational systems is now

more assessable. Increased competition should provide improved response, higher technological equipment, and lower costs. The demands of the user are dictating the future of this capability.

Existing multispectral systems and the combination of emerging systems, technologies, and employment capabilities can provide the imaginative consumer of visual intelligence a cornucopia of new and potent resources. Multispectral imagery augmentation to intelligence, whether used to support combat or Low Intensity Conflict operations, can make deployed forces more capable, efficient, effective, and lethal. These systems are operational and available now.

ENDNOTES

¹ Earth Observation Satellite Company Brochure, Lanham, MD, LANDSAT, undated, p. 1. This quote was used in the title page of the brochure. It is so prophetic and appropriate it deserves visibility in the opening line of this paper.

² Interviews conducted in December 1989 with members of US Army Special Operations Command, Ft Bragg, provided a general current that MSI products were usually not very useful to assist in the planning at the operational and tactical level.

³ U.S. Department of the Army, Field Manual 100-20, Military Operations in Low Intensity Conflict (Final Draft), Washington, 28 June 1989, p. 1-1. (Hereafter called "FM 100-20").

⁴ Floyd F Sabins, Jr., Remote Sensing Principles and Interpretation, New York, Freeman, 1987, p. 1.

⁵ Ibid., p. 3.

⁶ Ibid., p. 5-7.

⁷ Diagrams taken from Sabins, pp. 4-5.

⁸ LANDSAT, p. 25.

⁹ Sabins, pp. 78-79.

¹⁰ Ibid., p. 78.

¹¹ Ibid., p. 86.

¹² Earth Observation Satellite Company, Landsat Briefing, Lanham, MD, November 1987.

¹³ Melvin B. Satterwhite, Integrating Multispectral Imagery and Ground Level Hyperspectral Signature Data, Fort Belvoir, VA: U.S. Army Topographic Laboratories, p. 3.

¹⁴ Landsat Briefing, November 1987.

¹⁵ Airborne Visible Infrared Imaging Spectrometer. "This system now in the R&D community can provide 220 bands of imagery."; Satterwhite, p. 2.

¹⁶ Sabins, pp. 117-122.

¹⁷ Sue Davis, Fort Leavenworth, KS, U.S Army Space Institute, Briefing, Multispectral Imagery. Undated.

-
- 18 LANDSAT, p. 29.
- 19 Sabins, pp. 207-313, 317-344, 377-395.
- 20 FM 100-20, pp. 2-1 : 2-34.
- 21 Ibid., pp. 2-15 : 2-40.
- 22 Ibid., p. 3-1.
- 23 Ibid., pp. 3-1 : 3-16.
- 24 Ibid., pp. 5-1 : 5-6.
- 25 Photographs provided by Environmental Research Institute of Michigan, PO Box 8616, Ann Arbor, MI 48107. Reprinted by permission, MS. Judy Steeh, ERIM.
- 26 Memorandum of Understanding (MOU) between the United States Army and United States Geological Survey for the development, implementation and procurement of multispectral imagery and other digital imaging systems, p. 2.
- 27 Ibid., pp. 3-6.
- 28 Ibid., pp. 3-6.
- 29 Interview with Sue Davis, ARSPACE Liaison Officer, John F Kennedy Special Warfare Center and School, Fort Bragg, NC, 4 December 1989.
- 30 XVIII Airborne Corps visual graphic.
- 31 Davis, interview.
- 32 Ibid.
- 33 Satterwhite, pp. 1-13.