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IMPROVING THE ENGINEER RECONNAISSANCE REPORTING PROCESS THROUGH THE USE OF DIGITAL IMAGERY AND HANDHELD COMPUTERS

by

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This thesis explores an automated solution to improve the Engineer Reconnaissance Reporting Process. It proposes a proof-of-concept to enhance and improve the digital portion of the reporting process. This thesis defines the current process identifying its capabilities, limitations, and deficiencies. It identifies a prototype suite of equipment to perform the automation. The prototype capitalizes on the inherent capabilities on the reporting process and minimizes the deficiencies.

This thesis investigates emergent Commercial-off-the-Shelf components to locate those devices that satisfy the requirements and take full advantage of current technological advances. It evaluates each component against a criteria of minimum requirements and selects the most compatable device. This thesis performs an actual implementation of the prototype testing its performance against a fictional scenario. It provides a step-by-step description and graphic representation of the implementation. This thesis analyzes and summarizes the data generated during the implementation and provides recommendations. Results of this analysis suggest implementation of the prototype is feasible and that it satisfies the imagery portion of the Engineer Reconnaissance Reporting Process.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF ACRONYMS

AO	Area of Operation
BLT	Battalion Landing Team
Bn	Battalion
COTS	Commercial-of-the-Shelf
CSS	Combat Service Support
GCCS	Global Command and Control System
GPS	Global Positioning System
GUI	Graphical User Interface
HMMWV	High Mobility Multipurpose Wheeled Vehicle
HPC	Hand-Held Personal Computer
ISP	Internet Service Provider
JPEG	Joint Photographic Experts Group
LAR	Light Armored Reconnaissance
LCD	Liquid Crystal Display
LD	Line of Departure
LOA	Limit of Advance
METT-T	Mission, Enemy, Terrain and Weather, Troops and fire support available, Time
PDA	Personal Digital Assistant
PIR	Priority Intelligence Requirement

OBSTINTEL	Obstacle Intelligence
OODA	Observe, Orient, Decide, Act
OPORD	Operation Order
OTH	Over the Horizon
PL	Phase Lines
RAM	Random Access Memory
ROM	Read Only Memory
RP	Release Point
SINCGARS	Single-Channel, Ground-to-Air Radio System
SOP	Standard Operating Procedures
SP	Start Point
VGA	Video Graphics Array
WinCE	Windows CE

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I. INTRODUCTION

A. BACKGROUND

Engineers and engineer reconnaissance have played a vital and inseparable role of the combined arms team since the Revolutionary War. Engineer reconnaissance provides the unit commander with critical offensive and defensive information about the battlefield, which assists him in his decision-making processes.

However, in spite of recent technological advances, the Engineer Reconnaissance Reporting Process has remained virtually unchanged. After receiving their orders, the engineer reconnaissance units are sent forward to assess a specific route, area, or zone. Upon arrival at the objective, the unit performs a site survey; a process of identification and classification of encountered obstacles. Then, using a variety of different publications, they complete the necessary forms/reports with each obstacle requiring a unique report. Most reports are two-sided; one side being textual and the other side providing an area for a graphical depiction of the route, bridge, tunnel, etc. The team then either transmits the information via radio (line-by-line), or hand delivers the report to the higher headquarters. While the textual information can be transmitted via the radio, the graphical depiction must be hand-delivered. The Engineer Reconnaissance Reporting Process presently requires several individuals to record, transmit, and decipher the information. The entire process can take up to a full day to complete, diminishing the unit commander's decision-making capability. The speed and accuracy of the process are directly related to the knowledge and capabilities of the individuals involved.

The leverage of current and future commercial-off-the-shelf (COTS) technologies could enable the Engineer Reconnaissance Reporting Process to provide timely and accurate information (text and imagery) to the unit commander. The information would be provided in a digital format allowing further processing and enhancement of the decision-making capability of the unit commander.

B. OBJECTIVES

The purpose of this thesis is to identify a prototype equipment suite and associated procedures that will automate the Engineer Reconnaissance Reporting Process, providing the unit commander with responsive and reliable information in a digital format. This thesis proposes a proof-of-concept implementation of a lightweight man-portable suite of equipment that will satisfy the engineer reconnaissance requirement. The proposed system will take full advantage of the current COTS hardware and software technologies; such as Hand-Held Personal Computers (HPC), digital cameras, Global Positioning Systems (GPS), and wireless transmission devices (cellular phones).

The objective is to develop a system that is capable of delivering real-time imagery and data from forward deployed reconnaissance units to the unit commander in the rear, enhancing his decision-making capabilities. This research presents the requirements, architectural design, initial integration, and a proof-of-concept demonstration of an experimental prototype. The system will provide high levels of availability, compatibility, and flexibility. The initial proof-of-concept demonstration sets the stage for further testing and evaluation.

This thesis examines the following research questions:

1. What are the functional requirements and constraints of the engineer reconnaissance units?

2. What is the appropriate system architecture to automate the Engineer Reconnaissance Reporting Process?

3. How can the system be effectively implemented and used?

4. What are the constraints of using such a system?

C. ASSUMPTIONS

The success or failure of a unit in battle relies heavily on the decisions of the unit commander and subordinate leaders. The decision-making process employed by commanders is generally referred to as the OODA loop; Observe, Orient, Decide, and Act. The faster a commander can make decisions (the faster his OODA loop), the more he can force his will upon the enemy. Generally, the victorious commander in battle will be the one with the fastest OODA loop, forcing the enemy to react to his decisions. The decisions made by the unit commander rely heavily on the speed and accuracy of the information available at the time. The speed and accuracy of the information either enhances or reduces the decision-making process. Engineer reconnaissance units provide vital information to the unit commander to enhance his decision-making ability. The current Engineer Reconnaissance Reporting Process does not meet the response and reliability requirements of the unit commander.

D. METHODOLOGY

The following methodology was used in the preparation of this thesis:

1. Analysis of the requirements for Marine Corps Engineer Reconnaissance and the Engineer Reconnaissance Reporting Process.
2. Research of the current COTS hardware/software technologies to include: HPCs, digital cameras, wireless transmitters, and GPS's.
3. Development of a prototype suite of equipment in support of the Engineer Reconnaissance Reporting Process utilizing current technologies.
4. Conduct of a proof-of-concept implementation of the prototype suite of equipment to demonstrate the functionality as it applies to the Engineer Reconnaissance Reporting Process.

E. ORGANIZATION OF THE THESIS

Chapter II provides background information on engineer reconnaissance. It defines both traditional reconnaissance and engineer reconnaissance, and emphasizes the difference between them. It concludes with the requirements for engineer reconnaissance, giving historic examples and describes the current capabilities, limitations, and constraints involved with engineer reconnaissance.

Chapter III describes the methodology involved in evaluating the prototype suite of equipment. It discusses the analysis of the minimum requirements, design selection, and process development.

Chapter IV provides an in-depth depiction of a fictional engineer route reconnaissance scenario.

Chapter V provides a description and graphic depiction of the implementation of the prototype suite of equipment. It also reveals the results of the testing of the prototype and discusses the summary of the research to include the lessons learned and conclusions.

Chapter VI provides recommendations and suggestions for further study, to include the processes and equipment.

II. OVERVIEW OF ENGINEER RECONNAISSANCE

A. INTRODUCTION

Combat power is generated by combining the elements of maneuver, firepower, force protection, and leadership within a sound plan and then aggressively, violently, and flexibly executing the plan to defeat an enemy. The key to using combat power effectively is gathering information about the enemy and the area of operations (AO) through reconnaissance. A reconnaissance provides current battlefield information that helps a commander plan and conduct tactical operations. A reconnaissance greatly enhances maneuver, firepower, and force protection when properly executed. [FM 5-170, 1998]

This chapter presents an overview of engineer reconnaissance, providing the background and process. It begins by defining reconnaissance in its traditional roles. Engineer reconnaissance will be defined, this definition providing the differentiation between the engineer reconnaissance functions and traditional reconnaissance. The chapter will conclude with a review of the engineer reconnaissance process that will identify the current capabilities and limitations.

B. TRADITIONAL RECONNAISSANCE DEFINED

The commander needs information about the enemy and the terrain he controls or wants to control. He must have accurate and timely information to assist him in making tactical decisions. Reconnaissance patrols are one of the most reliable sources of this information. [FMFM 6-5, 1991] It is a mission undertaken to obtain, by visual observation or other detection methods, information about the activities and resources of an enemy, potential enemy, or the geographic characteristics of a particular point/area. [FM 7-92, 1992] Reconnaissance missions are normally broken down into three types; area, zone, and route.

Area reconnaissance is a directed effort to obtain information concerning the specific terrain or enemy activity within a prescribed area, such as a bridge or other features that are critical to operations.

Zone reconnaissance focuses on obtaining detailed information concerning routes, obstacles, terrain, and enemy forces within a particular zone defined by specific boundaries. A zone reconnaissance is assigned when the enemy situation is vague or when information concerning cross-country trafficability is desired.

Route reconnaissance focuses on obtaining information on a specific route and all terrain from which the enemy could influence movement along that route. Route reconnaissance can be oriented on a road, a narrow axis, or a general direction of attack.

C. ENGINEER RECONNAISSANCE DEFINED

An engineer reconnaissance unit's primary mission is collecting tactical and technical information for the supported or parent unit. The team must be able to perform this mission mounted or dismounted, during the day or at night, and in various terrain conditions. [FM 5-170, 1998] Engineer reconnaissance can be divided into two missions: tactical and technical. A tactical reconnaissance is conducted to gain information forward of friendly line or to provide current, accurate information about terrain, resources, obstacles, and the enemy within a specific Area of Operation (AO). This information provides the follow-on forces with an opportunity to maneuver freely and rapidly to their objective. [FM 5-170, 1998] Similar to traditional reconnaissance missions, engineer reconnaissance units can be involved in three different types of tactical reconnaissance: route, zone, and area. Additionally, during a tactical reconnaissance, engineers may also be involved in various technical reconnaissances such as:

1. Road reconnaissance—determining a road's trafficability by conducting soil analysis (if not paved), determining surface composition, roadway width, gradient, number of turn-around points, and degrees of curvature.
2. Route Reconnaissance—collecting information on routes along the axes of advance or withdrawal that may influence the commander's plan.
3. Bridge Reconnaissance—determining a bridge's classification to include type and length, load bearing capacity, estimation of required repairs, and demolition requirements for its destruction.
4. Obstacle Reconnaissance—locating, recording, and possibly marking all natural and man-made obstacles and providing estimates of breaching, spanning, or bypassing locations and requirements.
5. Tunnel Reconnaissance—determining critical dimensions, trafficability, hasty repair requirements, and demolition requirements for all types of tunnels.

6. Ford and Ferry Reconnaissance—locating possible ford and ferry sites, determining depth of crossing, streambed materials, access and egress routes, back configuration, and water flow velocity.
7. Threat Engineer Reconnaissance—identifying and evaluating threat engineer forces, equipment, capabilities, and activity.

D. REQUIREMENTS FOR ENGINEER RECONNAISSANCE

1. Historic Examples of Engineer Reconnaissance

The requirement for and the usage of engineer reconnaissance can be found throughout our military history. General George Washington articulated his requirement for engineer reconnaissance by issuing orders to his sappers (combat engineers) to precede the vanguard to open and mend roads and remove obstacles. General Washington's orders demonstrated our requirement for engineer recon skills and provides an example of road and route reconnaissance. [Sapp, 1996]

The requirement for engineer reconnaissance did not decrease during the 1900's and there are countless examples of its usage during both the World Wars. A poignant example of the requirement was demonstrated before the Normandy invasion in World War II. Prior to the D-Day invasion in 1944, the United States Army combat engineers reconnoitered and breached the German minefields so the Allied forces would have a near minefree avenue of approach to the beach. [Turque and Wilkinson, 1991]

Examples can also be found from both the Korean and Vietnam wars. During the Korean War, United States Marines conducting a bridge reconnaissance mission allowed fellow Marines to span a bridge destroyed by North Korean sappers. The bridge reconnaissance and restoration missions allowed the Marines to tactically withdraw from the Chosin Reservoir. [Montross and Canzona, 1957] During the Vietnam War, roads were a major concern of U.S. commanders. In some operations, infantrymen provided security as U.S. Army engineers improved neglected routes. Defoliants and the Rome plow—a bulldozer modified with sharp front blades—removed the jungle growth from the sides of important highways that provided cover for Viet Cong ambushes. Road-clearing operations also contributed to pacification by providing peasants with secure access to local markets. [American Military History, pg. 646]

Finally, a more recent example of the requirement for engineer reconnaissance was demonstrated during DESERT SHIELD/DESERT STORM. Marines from the 1st Marine Division were responsible for locating and identifying Iraqi minefields and other obstacles. The reconnaissance missions provided vital information to Marine commanders, assisting in their decision-making abilities during the first few hours of the ground war.

2. Current and Projected Requirements for Engineer Reconnaissance

The requirement for engineer reconnaissance has not diminished since DESERT SHIELD/DESERT STORM, but has increasingly become more important to unit commanders. The demand for engineer reconnaissance is not expected to decrease in the future, but will continue to provide valuable information about the battlefield. Commanders will continue to rely on it and it will become one of their most important assets in their decision-making processes.

Technology of the 21st century will demand a 21st century engineer soldier equal to the sophisticated systems of the future. Only intelligent, physically fit, highly motivated, educated, and well-trained engineers can leverage technology to its full potential. Electronic connectivity between and among all echelons in the Army will result in such speed and precision in communications that operational- and tactical-situation awareness and agility will far exceed that of today's forces. By 2010, the battlefield will be digitized. Incorporating digital technology will give commanders unprecedented capabilities to gather and share tactical information. Engineers will provide three-dimensional virtual terrain products of the battle space for all forces. [FM 5-100, 1996]

Presently, the Marine Corps is not leveraging current technology when it comes to engineer reconnaissance as evidenced by the following list of publications and reports:

	Publications	**Date**
FM 5-34	Engineer Field Data	14 September 1987
FM 5-100	Engineer Operations	27 February 1996
FM 5-170	Engineer Reconnaissance	5 May 1998
FM 7-92	The Infantry Reconnaissance Platoon and Squad	23 December 1992
FMFM 6-5	Marine Rifle Squad	2 December 1991
FMFM 13	Engineer Operations	February 1992

TABLE 2.1 ENGINEER RECONNAISSANCE PUBLICATIONS.

Reports	Date
DA 1248 Road Reconnaissance	1 July 1960
DA 1249 Bridge Reconnaissance	1 July 1960
DA 1250 Tunnel Reconnaissance	1 January 1955
DA 1251 Ford Reconnaissance	1 January 1955
DA 1252 Ferry Reconnaissance	1 January 1955
DA 1711-R Engineer Reconnaissance	May 1985

TABLE 2.2 ENGINEER RECONNAISSANCE REPORTS.

E. CURRENT ENGINEER RECONNAISSANCE PROCESS (Capabilities/Limitations):

The desired result of the engineer reconnaissance process is to provide timely and accurate information to the unit commander. The information will enable the commander to make faster, more sound decisions, which ultimately could have a profound impact on the battle, as the historic examples cited earlier illustrated. However, to achieve the desired result the engineer reconnaissance team must know the fundamentals of a successful reconnaissance operation, the teams capabilities/limitations, and its Standard Operating Procedures (SOP) (a step-by-step description of the process).

FM 5-170 lists the six fundamentals common to all successful reconnaissance operations, whether the operation is traditional reconnaissance or engineer reconnaissance. The fundamentals are:

1. Use maximum reconnaissance force forward
2. Orient on the reconnaissance objective

3. Report all information rapidly and accurately
4. Retain freedom of maneuver
5. Gain and maintain enemy contact
6. Develop the situation rapidly

Additionally, FM 5-170 outlines the current engineer reconnaissance team capabilities are to:

- Assist in gathering basic enemy information.
- Provide detailed technical information on any encountered obstacle.
- Conduct an analysis of what assets will be needed to reduce any encountered obstacle.
- Provide detailed technical information on routes (including classification) and specific information on any bridges, tunnels, fords, and ferries along the route.

FM 5-170 outlines the following limitations of an engineer reconnaissance team:

- The reconnaissance team has a limited ability to destroy or repel enemy recon units and security forces.
- The distance the engineer reconnaissance team can operate away from the main body is restricted to the range of communications, the range of supporting indirect fires, and the ability to perform Combat Service Support (CSS) operations.
- The reconnaissance team has a limited communications capability. The single-channel, ground-to-air radio system (SINCGARS), carried by the recon team

should be able to scan critical engineer nets or, at the very least, easily switch to the engineer net to report obstacle intelligence (OBSTINTEL).

Interviews with Marines of the 1st and 2nd Combat Engineer Battalions revealed the current Marine Corps engineer reconnaissance process varies slightly from the East Coast to the West Coast and from unit to unit. Each unit may have a slightly different SOP, depending upon the mission that unit is responsible for accomplishing. However, the basic concepts and procedures of sending units forward, gathering information, and transmitting the processed information to the commander is consistent throughout the Marine Corps.

1. Engineer reconnaissance teams are task organized, usually squad sized.
2. The teams receive their orders from the Battalion (Bn) S-2 (Intelligence Officer) or their platoon or battalion commander. They are sent forward with the most current information at that time.
3. The team then moves to the objective. Movement will be either mounted (High Mobility Multipurpose Wheeled Vehicle (HMMWV), Light Armored Reconnaissance (LAR), or helicopter) or dismounted (by foot).
4. Upon arrival at the objective, the team begins performing a site survey. The site survey consists of an inspection and classification of the objective. Inspection is done by visually inspecting the objective and taking appropriate measurements. The gathered information is then computed and recorded using a number of different publications and reports that the team carried with them. The objective will then be classified as the type of bridge, road, tunnel, etc.

Additionally, during the inspection and classification phase, a graphical depiction of the objective will be hand-drawn on the reverse side of the report. When delivered to the unit commander, the sketch will provide a depiction of the objective, assisting him in his decision making.

5. The team then transmits the information recorded on the report, by radio, to the S-3 (Operations Officer) or the S-2. The report is relayed line-by-line, duplicating the information on the report at both ends.
6. The team then moves back to the rear, their original location. The team completes any computation, sketch, or report that may have not been finished. The team then reconciles their report with the transmitted report and presents their graphical depiction of the obstacle.

The process can take several hours to an entire day to complete. The speed and accuracy of the process depends heavily on the individuals doing the reconnaissance and relaying or transcribing of the information over the radio. Finally, one of the commander's greatest assets, the eyes of his reconnaissance team, is underutilized. The team must first hand-draw the objective and then hand-deliver the depiction to the commander; a process that wastes precious time and squanders a potential advantage that should have been exploited.

F. SUMMARY

Reconnaissance, either traditional or engineering, is a valuable tool that a unit commander uses to enable him to make faster and more informed decisions. This research proposes a proof-of-concept suite of equipment that will automate the Engineer Reconnaissance Reporting Process. The proposed solution must operate under the following constraints.

1. Be lightweight and man-portable, so not to constrict or hinder the movement of the engineer. The proposed solution will add greater flexibility and efficiency by removing heavy, older items (i.e., publications and radios) and replacing them with smaller, lighter, more capable items (i.e., cellular phones and handheld computers).
2. Take full advantage of available lines of communication. It will provide voice communications as well as the capability of sending and receiving data transmissions, instead of relying solely on the voice communications provided by the radio.
3. Take full advantage of COTS technologies applicable to the processing of the information (imagery) provided by the engineer reconnaissance process. Using existing and emerging COTS technologies it will provide an immediate solution to the problem as compared to the lengthy DoD acquisition process.
4. Provide the exact location of the team. The integration of a GPS will provide the exact latitude, longitude, and bearing of the obstacle or location of the engineers.
5. Provide information that is responsive and timely. It will provide immediate visual feedback in a digital format concerning a location or obstacle, instead of

the delay associated with waiting for the return of the engineer team and their hand-drawn sketch.

6. Provide information that is accurate, clear, and concise. It will provide the accuracy and clarity of a data transmission of text and imagery, instead of the ambiguity and uncertainty usually associated with a radio transmission.
7. Provide detailed information that can be used for the classification of obstacles. It will provide the information in a digital format for easy manipulation and storage, instead of the data being provided in a hand-written format.
8. Be capable of being operated by personnel with limited training. The COTS technologies provide a solution that can be mastered in a short period of time, instead of the current system, which may take years to gain adequate proficiency.

III. METHODOLOGY FOR THE AUTOMATION OF THE ENGINEER RECONNAISSANCE PROCESS

A. INTRODUCTION

> The Marine Corps, as it has always done when faced with uncertainty and challenge, is turning to our unequaled ability to innovate and adapt. Just as we did at Culebra prior to World War II, we are today, turning to experimentation. We are looking at new tactics, new organizations, and new technologies. Some experiments will succeed, some will fail, all will help us prepare a capable force for the uncertainties ahead.
>
> General Charles C. Krulak, Commandant of the Marine Corps

This chapter proposes a man-portable suite of equipment that will enhance the decision-making capabilities of unit commanders in the Marine Corps. The proposed system will take full advantage of the current COTS technologies and equip forward units (i.e., reconnaissance units or engineering survey teams) with the system. The teams would literally be the forward eyes of the commander. The teams would have the capability of capturing images of varying resolution and compression. The compressed images would then be wirelessly transmitted to the commander. The chapter also outlines the analysis of the minimum requirements, design selection, and development processes used to select the individual components that will automate the Engineer Reconnaissance Reporting Process.

B. PURPOSE OF PROOF OF CONCEPT DEMONSTRATION

The purpose of the proof of concept is to match the eight constraints generated in Chapter II with a prototype suite of equipment, taking full advantage of current COTS technologies. This prototype will equip a Marine performing engineer reconnaissance with a handheld computing device, digital camera, cellular phone, global positioning system, and associated cables and connectors. The heart of the system will be the handheld computer; all other components must connect to and be compatible with it. The handheld computer will provide the necessary processing, storage, and communication functionality for the prototype. The digital camera will eliminate the need for the hand-drawn sketches and will provide the capability to digitally capture specific items (i.e., locations or obstacles) for faster delivery via electronic transmission. The cellular phone and accompanying PC-Card modem will be the communications media for the prototype, replacing the radio. It will provide the capability of both voice and data communications. The GPS is the final component of the prototype. It provides the necessary precision and accuracy needed in the location and identification of obstacles. The prototype will automate the imagery portion of the current process of the Marine engineer. It will provide greater flexibility, clarity, and accuracy in the capture and transmission of information to better accomplish their mission.

C. MINIMUM REQUIREMENTS AND DESIGN SELECTION

1. Handheld Personal Computer (HPC)

The HPC is a small mobile processing device that has only recently entered the computer market, but already has created a big impact. The HPC is the heart of the prototype. It has been called by many names in its short existence: HPC, Personal Digital Assistant (PDA), PalmTop, or personal companion. The devices are roughly broken down into three categories: Apple Newton (MessagePad), 3Com (PalmPilot), and Windows CE (WinCE) compliant. WinCE is a scaled down version of the Windows operating system for mobile computing devices. Selection of a category for the prototype was made easier through Navy and Marine Corps technology standardization. The Navy has currently based their technology plan, "IT21", around Microsoft Office and Windows NT. Accordingly, the Commandant of the Marine Corps has directed the Marines to comply with IT21, eliminating both the Newton and 3Com mobile computing platforms as potential candidates. Companies that are currently manufacturing WinCE devices include: Hewlett-Packard, Phillips, Sharp, LG Electronics, and NEC, just to name a few. The differences between individual brands and devices reside in the cost, amount of RAM/ROM, availability of serial connectors, flash memory and PC-card slots, and use of color LCDs.

a. Minimum Requirements

During the analysis of the requirements, the minimum capabilities were determined by establishing what functionality was required to perform the proof-of-concept. The following capabilities are required for the HPC:

1. It must be compatible with all the other components and capable of interfacing with all the other components simultaneously.
2. It must be Windows CE 2.0 compliant. Version 2.0 is the current release of WinCE and provides added functionality that was not available in Version 1.0.
3. It must have a flash memory slot. The flash memory slot will provide the interface with the digital camera for image transfer.
4. It must have a Type II PC-card slot. The PC-card slot provides the interface with the cellular modem PC-card for wireless communication.
5. It must have a serial port. The serial port will provide the necessary interface with the GPS.
6. It must have a minimum of 16 level grey-scale LCD, but without having a color display. A grey-scale LCD more efficiently utilizes the life of the battery and can be viewed in direct sunlight.
7. It must have a minimum of 8 MB of RAM and 8 MB of ROM. The RAM and ROM will provide the space needed for the GPS and additional software.
8. It must have the capability to send and receive Internet Email.

b. Design Selection

During the selection phase, specific components were identified. The search for possible components was narrowed down based upon the minimum capability criteria generated during the analysis phase. Each component was then selected based upon its ability to satisfy the functionality and requirements necessary to perform the proof-of-concept. Ten different handheld computers were evaluated to select the handheld that met the requirements.

Manufacturer/ Model	**OS**	**RAM ROM**	**LCD**	**Serial**	**PC-Card**	**Compact Flash**
Hewlett Packard HP320 LX	WinCE 1.0	4MB 5MB	Grey 640x240	YES	(1) Type-II	YES
Hewlett Packard HP360 LX	WinCE 2.0	8MB 10MB	Grey 640x240	YES	(1) Type-II	YES
NEC MobilePro 400	WinCE	4MB 8MB	Grey 480x240	YES	(1) Type-II	NO
NEC MobilePro 700	WinCE 2.0	8MB 16MB	Grey 640x240	YES	(1) Type-II	NO
Phillips Velo-1	WinCE	8MB 8MB	Grey 480x240	YES	NO	YES
Phillips Velo-500	WinCE	16MB 16MB	Grey 640x240	YES	NO	YES
Sharp Mobilon HC-4100	WinCE 2.0	12MB	640x240 Grey	YES	(1) Type-II	NO
Sharp Mobilon HC-4500	WinCE 2.0	16MB	Color 640x240	YES	(1) Type-II	NO
LG Electronics Phenom	WinCE 2.0	4MB 8MB	Grey 480x240	YES	(1) Type-II	YES

TABLE 3.1 HANDHELD PERSONAL COMPUTER MINIMUM REQUIREMENTS.

The HPC selected for the proof-of-concept was the HP360LX (Figure 3.1). The selection was made based upon the following specifications:

1. The HP360LX comes loaded with the Windows CE 2.0 operating system and the following software: Pocket Office, Internet Explorer, and Inbox email software.
2. It has all the necessary peripherals: flash memory to interface with the digital camera, a PC-card slot for communication, and a serial port for the GPS.
3. The LCD is 640x240 (1/2 VGA) and is 16-color gray scale. The LCD is capable of being viewed in bright sunlight and saves battery life.
4. It is equipped with 8MB of RAM and 10MB of ROM. It provides sufficient space for preloaded software and the necessary storage space for the GPS software.

Figure 3.1 HP360LX Handheld Personal Computer.

2. Digital Camera

Digital cameras are another class of device that has also rapidly emerged onto the scene. Digital cameras provide the capability of capturing images in a digital format for transfer to another media for further processing. Digital cameras are also being developed by many manufacturers: Kodak, Canon, Nikon, and Olympus are just a few of the industry leaders. The differentiating factors that were examined between potential camera candidates were cost, resolution, compression, zoom capability, and storage media.

a. Minimum Requirements

During the analysis of requirements, the minimum capabilities were determined by establishing what functionality was required to perform the proof-of-concept. The following are the capabilities required for the digital camera:

1. It must cost less than $1,000.
2. It must have the ability of varying resolution, with maximum resolution greater than 640x480. The greater resolution allows images to be taken with greater detail. It also provides the unit commander the added flexibility to decide what resolution is needed.
3. It must provide differing levels of compression. Compression reduces the image size and allows more images to be stored and a faster transmission time.
4. It must provide the capability to store the images to a compact flash memory card. The compact flash memory card will provide the interface with the HPC.
5. It must have the capability of storing the images on the Compact Flash memory card in the JPEG format. JPEG is a widely used compression algorithm for imagery and is not manufacturer proprietary.
6. It must have the capability to view and review the images on the camera's LCD. The images will be initially viewed on the camera before being transferred to the HPC via the flash memory card.

7. It must have both zoom and auto focus capability which provide the added functionality the recon units will need in the accomplishment of their mission.

b. Design Selection

The search for the digital camera was narrowed down based upon the minimum capability criteria generated during the analysis phase. Nine different digital cameras were evaluated in the selection of the camera. The camera chosen was selected based upon its ability to satisfy the functionality and requirements necessary to perform the proof-of-concept.

Manufacturer Model	**Price**	**Resolution**	**Compression**	**Zoom Focus**	**Image Format**	**Memory Card**	**LCD**
Cannon Powershot 600	$699	832x608	3 Levels	NO Fixed	JPEG	Flash Memory	NO
Kodak DC50	$499	756x504	3 Levels	3X Auto	JPEG	Optional	NO
Kodak DC120	$799	1280x960	4 Levels	2X Auto	JPEG	Optional	YES
Kodak DC210	$699	1152x864	3 Levels	3X Auto	JPEG	Flash Memory	YES
Ricoh RDC-2	$799	768x576	3 Levels	NO Auto	JPEG	Flash Memory	YES
Ricoh RDC-2E	$499	768x576	3 Levels	NO Auto	JPEG	Flash Memory	YES
Olympus D-320L	$499	1024x768	3 Levels	NO Fixed	JPEG	Smart Media	YES
Olympus D-500L	$799	1024x768	3 Levels	3X Auto	JPEG	Smart Media	YES
Olympus D-600L	$1200	1280x1024	3 Levels	3X Auto	JPEG	Smart Media	YES

TABLE 3.2 DIGITAL CAMERA MINIMUM REQUIREMENTS.

The Kodak DC210 (Figure 3.2) was the digital camera selected for the proof-of-concept based upon the minimum requirements and the following specifications:

1. The Kodak DC210 provides two levels of resolution. It is capable of capturing images at a maximum resolution of 1152 x 864 or a minimum of 640 x 480. The lesser resolution creates a smaller file size, which is ideal for faster transmission, but the trade-off is less definition.
2. It provides three levels of compression (good, better, and best). Again, reducing the levels of compression also reduces file size, but the price of faster transmission is a degraded image.
3. It is compact flash memory compatible and comes with a 4MB removable card. It can store up to 16 of the highest quality images or up to 60 lesser quality.
4. It comes with a color LCD for viewing and reviewing the images. It is equipped with a user-friendly menu system for reviewing the images.
5. It has a 2x zoom (29-58mm) and has an auto focus capability.
6. The images can be stored in JPEG or FlashPix format. JPEG is widely used as an industry standard for image compression and FlashPix is a Kodak proprietary image compression standard.

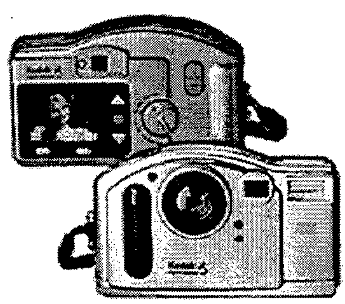

Figure 3.2 Kodak DC210 Digital Camera.

3. Communications Equipment

A reconnaissance unit must have the capability of wireless communication to more effectively perform their mission. They need the ability to wirelessly transmit information (imagery, location, and text) to their unit commander. Recent technological advances in cellular phones and PC-cards modems allow this to be possible.

a. Minimum Requirements

During the analysis of requirements the minimum capabilities were determined by establishing what functionality was required to perform the proof-of-concept. The following are the capabilities required for the PC-card modem:

1. It must be cellular phone capable, providing the wireless transmission of information.

2. It must be Windows CE 2.0 compatible to interface with the HPC.

3. It must be able to take advantage of the highest possible transmission speed. The higher the transmission speed the faster the images can be transmitted which will ultimately increase the battery life of all the components.

During the analysis of requirements, the minimum capabilities were determined by establishing what functionality was required to perform the proof-of-concept. The following are the capabilities required for the cellular phone:

1. It must be compatible with the PC-card modem.
2. It must be capable of analog transmission.

b. Design Selection

The search for the PC-card modem was narrowed down based upon the minimum capability criteria generated during the analysis phase. Ten different modem cards were evaluated during the selection process. The modem card was selected based upon its ability to satisfy the functionality necessary to perform the proof-of-concept.

Manufacturer/ Model	Cellular Phone Capable	WinCE Compliant	Transmission Speed
3Com Megahertz XJ5560	YES	YES	56K
Hayes 56k Accura	YES	YES	56K
Hayes 56K Optima	YES	YES	56K
Motorola MobileSurfr56K	YES	YES	56K
Simple Technologies 33.6k Communicator	YES	YES	33.6K
Simple Technologies 56k Communicator	YES	YES	56K
TDK Systems Cellular Companion	YES	YES	56K
Viking 33.6K PC Card	YES	NO	33.6K
Viking 56k PC Card	YES	YES	56K
Zoom Flash PC Card	YES	YES	56K

TABLE 3.3 PC-CARD MODEM MINIMUM REQUIREMENTS.

The MegaHertz XJ5560 (Figure 3.3) was the PC-card modem selected for the proof-of-concept based upon the minimum requirements and following specifications:

1. It is cellular phone capable and is compatible with several different cellular phones that are presently on the market.

2. The transmission speed is 56Kbps, the highest transmission speed available.
3. It is compatible with the handheld computer. The HP360 LX was able to automatically recognize the PC-card modem without user manipulation.

The selection of a cellular phone was significantly simplified after the PC-card modem was selected. It was further narrowed down based upon the minimum capability criteria generated during the analysis phase. Nine different phones that were compatible with the MegaHertz XJ5560 were evaluated during the selection process. The phone chosen was selected based upon its ability to satisfy the functionality and requirements necessary to perform the proof-of-concept.

Manufacturer/ Model	**Compatible with XJ5560**	**Analog Transmission**	**Required Cable**
AT&T 6650	YES	YES	CableNOK3
Motorola MicroTAC	YES	YES	CableMOT1
Motorola MicroTAC Elite	YES	YES	CableMOT2
Motorola TX400	YES	YES	CableMOT3
Motorola StarTAC 6000	YES	YES	CableMOT4
Nokia 232	YES	YES	CableNOK2
Nokia 2180	YES	YES	CableNOK3
Radio Shack 17-1062	YES	YES	CableNOK2
Technophone TD 815	YES	YES	CableNOK3

TABLE 3.4 CELLULAR PHONE MINIMUM REQUIREMENTS.

All nine of the cellular phones evaluated for the proof-of-concept satisfied the minimum requirements established during the analysis phase. Therefore the cellular phone that was selected for the proof-of-concept was based upon the availability of the phone and the associated cable. The Nokia 2180 and the associated cable (CableNOK3) were available at the time of the testing and therefore were selected for the proof-of-concept. As previously mentioned, the Nokia 2180 (Figure 3.3) satisfied the following criteria:

1. It is compatible with the Megahertz XJ5560 PC-card modem.
2. It is capable of both analog and digital transmission.

Figure 3.3 Megahertz XJ5560 PC-Card Modem and Nokia 2180 Cellular Phone.

4. Global Positioning System

The ability of a unit commander to know the exact locations of his forward units is an extremely useful decision-making tool. GPS provides recon units with this capability and consequently this data could be wirelessly transmitted to the unit commander. This would provide the unit commander with a picture of the precise locations of his assets from which he could make faster, more informed decisions.

a. Minimum Requirements

During the analysis of the requirements, the minimum capabilities were determined by establishing what functionality was required to perform the proof-of-concept. The following are the capabilities required for the GPS:

1. It must be Windows CE 2.0 compatible, in order to interface with the HPC.
2. It must come with software that will run on a HPC and desktop computer.
3. It must provide sufficient resolution to satisfy the proof-of-concept.

b. Design Selection

The GPS selected for the proof-of-concept was the Garmin GPS (Figure 3.4). The selection was made based upon the following specifications:

1. It can be used with any Windows CE handheld device.
2. It included Teletype GPS software for Windows CE. The software is easily loaded onto the handheld computer and provides a Graphical User Interface (GUI) for the GPS.

3. It comes in either 8 or 12 channel mobile package for HPC. The model chosen for the prototype was the 12 channel, providing additional accuracy.

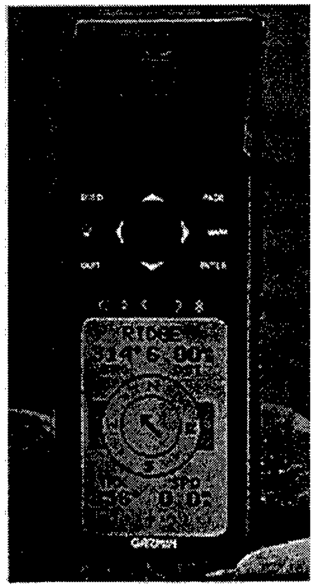

Figure 3.4 Garmin 12-Channel GPS.

5. Cabling and Connectors

In addition to ensuring each component of the prototype was compatible, cabling and connectors were also an issue. The digital camera required no additional or external hardware for the demonstration. However, the connection between the HPC and the GPS required two additional cables and one connector. All three components were ordered and received from Teletype. The connector is referred to as the HPC adapter and is used to connect the HPC serial cable to the Garmin serial cable. The HPC serial cable is connected from the serial port of the HPC to the HPC adapter. Teletype referred to the cable as a HP 300 Series Palmtop PCs (Part # HP F1223A). The Garmin serial cable is connected between the GPS and the HPC adapter. It is referred to as the Garmin PC Interface Cable (Part # 010-10141-00).

Finally, an additional cable was needed to connect the PC-card modem and the cellular phone. MegaHertz makes special cables depending upon the model of modem card and cellular phone that is being used. The interface cable between the MegaHertz XJ5560 and Nokia 2180 is the US Robotics cable NOK3. A graphic representation of the system is depicted in Figure 3.5.

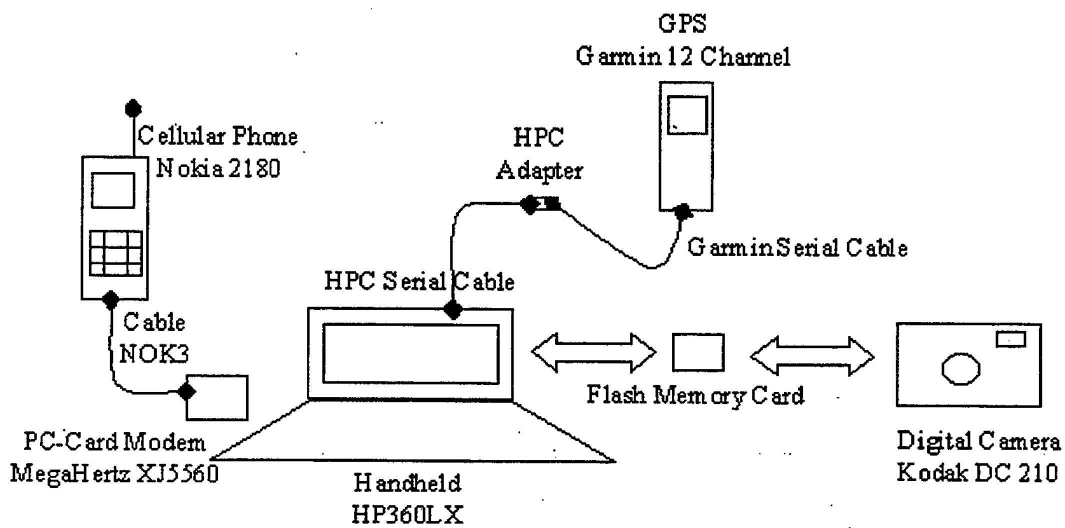

Figure 3.5 System Diagram.

D. DEVELOPMENT OF THE PROCESS

During the development phase, a twelve step procedure (Table 3.5) was established for testing the equipment and proof-of-concept. Each step tested a specific aspect of the proof-of-concept. Each step is first described as a task, than the actions required to accomplish the proof-of-concept, and finally, a statement envisioning how that task can be implemented in future iterations.

Task	Proof-of Concept	Future Implementation
1. The Marine will receive an order from the unit commander, either by voice or electronic means.	**Lab Participant**: Prior to issuing the order, a particular location will be designated as the objective. An order will then be issued, either by voice or data, to capture the digital image of that location. **Field Participant**: Receive the order.	The Marine will receive the tasking (voice or data) from the unit commander.
2. The Marine will move to the objective (ground, sea, or air).	**Field Participant**: Movement to the location accomplished by foot or vehicle.	The Marine will move to the objective either dismounted (by foot) or mounted (HMMWV, LAR, or helicopter).
3. Upon reaching the objective, the Marine will then establish communication (voice or data).	**Field Participant**: Upon reaching the designated location, establish communication with the lab participant, by cellular phone or email. **Lab Participant**: Provide any updated information or change the tasking.	Upon arrival at the objective, the Marine will contact the unit commander (voice or data). The unit commander can provide updated intelligence at that time.
4. The Marine will capture a digital image of the objective.	**Field Participant**: Several images of the objective will be taken using the two different levels of resolution (1152 x 864 and 640 x 480). Images will also be taken from different angles and distances. The images will be reviewed on the camera's LCD and unwanted images can be immediately deleted without any further processing.	The Marine will shoot several images of the objective at varying resolutions with differing angles and distances.

5. The Marine will compress the image for transmission, either on the camera or HPC.	**Field Participant**: The images will be compressed using the camera's compression algorithms (good, better, best). As stated in the previous step, several images of varying compression will be taken. The greater the compression that is applied to the image the faster the file will transfer, but the finer details will be lost.	The Marine will compress the images on the HPC via Thumbnail software for the fastest transmission time.
6. The Marine will transfer the images from the digital camera to the HPC.	**Field Participant**: The digital camera will store the images to the compact flash memory card. The flash card will be removed from the camera and inserted into flash memory slot on the HPC.	The initiation by the Marine to store the image to the compact flash memory card would also initiate the transfer function of the image to the HPC via cable. Future automation of the process would minimize the amount of intervention performed by the individual.
7. The Marine will receive and process the latitude, longitude, and bearing from the GPS for transmission.	**Field Participant**: After the images are transferred to the HPC, the latitude, longitude, and bearing will be taken from the GPS program running on the HPC. The images will be cross-referenced to a location (latitude, longitude, and bearing). An email message will be created which will contain the location and image number in preparation for transmission.	Initiation of the image storage function would also initiate the capture of the location (latitude, longitude, and bearing). The image would then be tagged and cross-referenced to a specific location. This future implementation would again limit the intervention the individual needs to perform during the process.

8. The Marine will connect to the unit's network using a wireless transmitter.	**Field Participant**: Using the cellular phone, connection will be established with either the school's network or a local Internet Service Provider (ISP) using username and password.	Initiation of the image storage function would also initiate connection to the network. The username and password would be preloaded onto the HPC, further automating the process.
9. The Marine transfers the image, location, and any other pertinent data to the unit commander using email.	**Field Participant**: After a network connection has been established, the data will be transferred using email to the lab participant. The images will be sent as attachments to an email message. As previously mentioned, the text of the email will contain a description of the images, image number, location and any other pertinent information.	Initiation of the image storage function would also initiate the transmission of the data in an agreed upon format.
10. The images will be received and interpreted by the unit commander.	**Lab Participant**: Periodically check his email and download the messages and attachments. The images will be sent as JPEG images so they can be readily viewed on a desktop computer.	The images would be sent to a central account, not to an individual. The users would receive an immediate notification upon the arrival of the images. The images would be deposited into repository where they could be interpreted by mulitple users.
11. The location would be received and interpreted by the unit commander.	**Lab Participant**: Retrieve and interpret the location from the email message. The exact locations from where the images were captured will be able to be ascertained from the latitude, longitude, and bearing.	The location will be deciphered automatically at the distant end, via software, and displayed on an electronic map.

12. The unit commander will provide feedback to the Marine, either by voice or data.	**Lab Participant**: Provide feedback (voice or data) to change the resolution, compression, or orientation of the image. He could also direct the team to go to a new location. Additionally, a portion of the image could be highlighted where a close-up is needed. The image would then be retransmitted to the distant end to be viewed.	The Marine will receive an immediate indication of the success or failure of the transmission. The Marine will also receive feedback, either voice or data, regarding the image and additional requirements.

TABLE 3.5 DEVELOPMENT OF THE ENGINEER RECONNAISSANCE PROCESS.

E. SUMMARY

This chapter outlines the methodology used in determining a prototype suite of equipment and the procedures for the automation of the Engineer Reconnaissance Process. The minimum requirements for each component were determined and from those criteria the following components were selected and displayed in Table 3.6

Component	**Manufacturer/ Model**	**Price**
Handheld Personal Computer	Hewlett Packard HP360 LX	$539
Digital Camera	Kodak DC210	$699
Global Positioning System	Garmin GPS 12	$399
Communication Equipment		
Cellular Phone	Nokia 2180	$275
PC-card Modem	Megahertz XJ5560	$179

TABLE 3.6 PROTOTYPE EQUIPMENT SUITE.

Additionally, a twelve-step process was created simulating the Engineer Reconnaissance Process. The twelve-steps describes the process, how it will be performed for the prototype testing, and the envisioned future implementation. The following chapters will discuss the implementation of the prototype, the analysis of the data, and recommendations for future testing.

IV. EXAMPLE OF ENGINEER ROUTE RECONNAISSANCE

A. INTRODUCTION

> ..it is certain that in future wars, even more than in the past, endeavors will be made by every possible means to prevent or delay the march of the enemy's troops by throwing obstacles in the way and by cutting such lines of communications as they might use.
>
> Conversely, in order to reach an objective, it will be necessary to overcome or destroy obstructions to the movements of troops and re-establish the continuity of highways and railroads in the most rapid and practical manner.
>
> Douglas MacArthur

This chapter provides an in-depth review of the engineer route reconnaissance mission. It then provides a scenario to demonstrate capabilities and limitations of the suite of equipment and 12-step procedure proposed in Chapter III. The scenario poses a realistic route reconnaissance mission and describes a possible implementation of the automation of the process.

B. ROUTE RECONNAISSANCE

Maneuver units or scouts, augmented by engineers, conduct a route reconnaissance to gain detailed information about a specific route and the terrain on both sides of the route that the enemy could use to influence movement. When the commander wants to use a specific route, a maneuver unit or scout platoon with an engineer reconnaissance team conducts a route reconnaissance. This ensures that the route is clear of obstacles and enemy forces and that it will support his vehicles' movements. Engineers supporting division cavalry squadrons and armored cavalry regiments will routinely support these units in route reconnaissance missions.

1. Critical Tasks

During a route reconnaissance, the reconnaissance element must accomplish a specified number of tasks unless directed to do otherwise. Based on time available and the commander's intent, the reconnaissance element may be directed to conduct a route reconnaissance to acquire specific information only. The reconnaissance leader must clearly understand which of the following critical tasks must be accomplished:

- Determining the route's trafficability.
- Reconning to the limit of direct-fire range and terrain that dominates the route.
- Reconning all built-up areas along the route (includes identifying bypass routes, construction supplies and equipment, ambush sites, and evidence of booby traps).
- Reconning all lateral routes to the limit of direct-fire range.
- Inspecting and classifying all bridges on the route.
- Locating fords or crossing sites near all bridges on the route (includes determining fordabilty and locating nearby bypasses that can support combat and CSS units, marking bridge classifications and bypass routes, and being prepared to provide guides to the bypasses).
- Inspecting and classifying all overpasses, underpasses, and culverts.
- Reconning all defiles along the route.
- Locating obstacles along the route.
- Locating bypasses around built-up areas, obstacles, and contaminated areas.
- Reporting route information.
- Finding and reporting all enemy forces that can influence movement.

2. Techniques

Because of the number of critical tasks that must be accomplished, a scout platoon with an engineer reconnaissance team can conduct a detailed reconnaissance of only one route. A scout platoon may be able to handle two routes if the reconnaissance is limited to trafficability only. The following discussion outlines one technique of accomplishing all tasks as rapidly and securely as possible.

The scout platoon leader receives an order specifying the route the platoon must reconnaissance and defining the route from start point (SP) to release point (RP). Additionally, the order may specify platoon boundaries, phase lines (PLs), lines of departure (LDs), and a limit of advance (LOA) or a reconnaissance objective. These control measures specify how much terrain on both sides of a route the platoon must reconnoiter and where the operation must begin and end. The boundaries are drawn on both sides and include the terrain that dominates the route, usually extending out 2.5 to 3 kilometers. This ensures that the scouts reconnoiter all terrain that the enemy could use to influence movement along the route. An LD is drawn from one boundary to the other behind the SP. This allows the platoon to cross the LD and be fully deployed before reaching the route. An LOA or objective is placed beyond the RP on the last terrain feature dominating the route or out to about 3 kilometers. Figure 4.1 graphically illustrates the control measures used by a scout platoon performing a route reconnaissance mission.

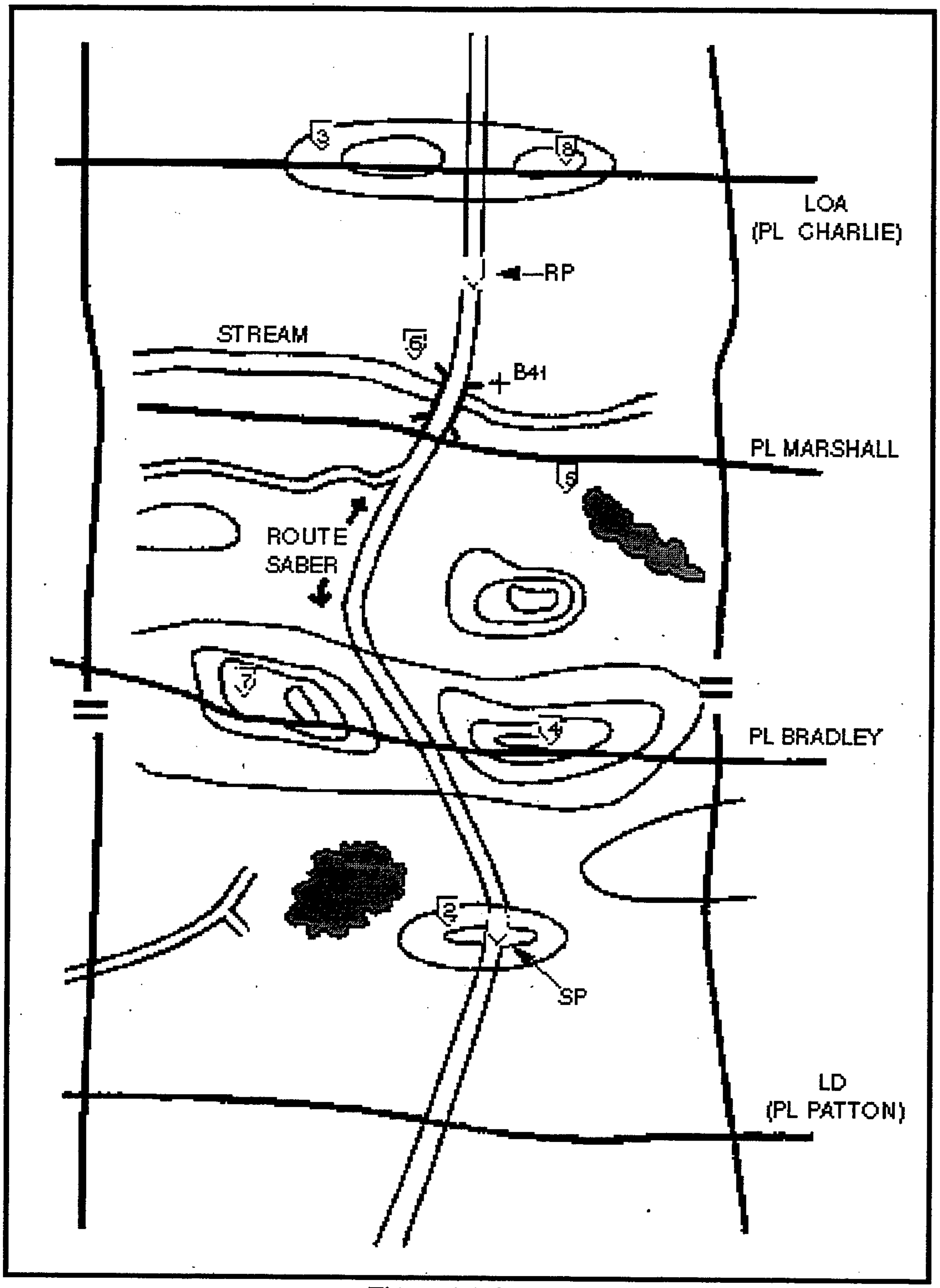

Figure 4.1 Control Measures.

The reconnaissance platoon leader may add additional PLs, contact points, and checkpoints to the graphics he receives from his commander. PLs are used to help control the platoon's maneuver. The contact points ensure that the teams maintain contact at particular critical points. Checkpoints are used along a route or on specific terrain to control movement or to designate areas that must be reconned. The engineer reconnaissance team leader should obtain this information during the scout platoon Operation Order (OPORD) briefing.

The reconnaissance platoon leader evaluates the METT-T (Mission, Enemy, Terrain and weather, Troops and fire support available, and Time) factors and organizes his platoon with an engineer reconnaissance team to meet mission needs. He ensures that at least one team is responsible for the reconnaissance of the route. A three-team organization is usually the type best suited to reconnaissance a route. Team A reconnoiters the terrain left of the route, Team B covers the terrain right of the route, and Team C and the engineer reconnaissance team reconnoiters the route and controls the movement of the other two teams. In this organization, the platoon leader's team has specific responsibility to clear the route. The engineer reconnaissance team's tasks will likely include a technical reconnaissance of the route. Figure 4.2 graphically illustrates the three-team organization combined with the control measures.

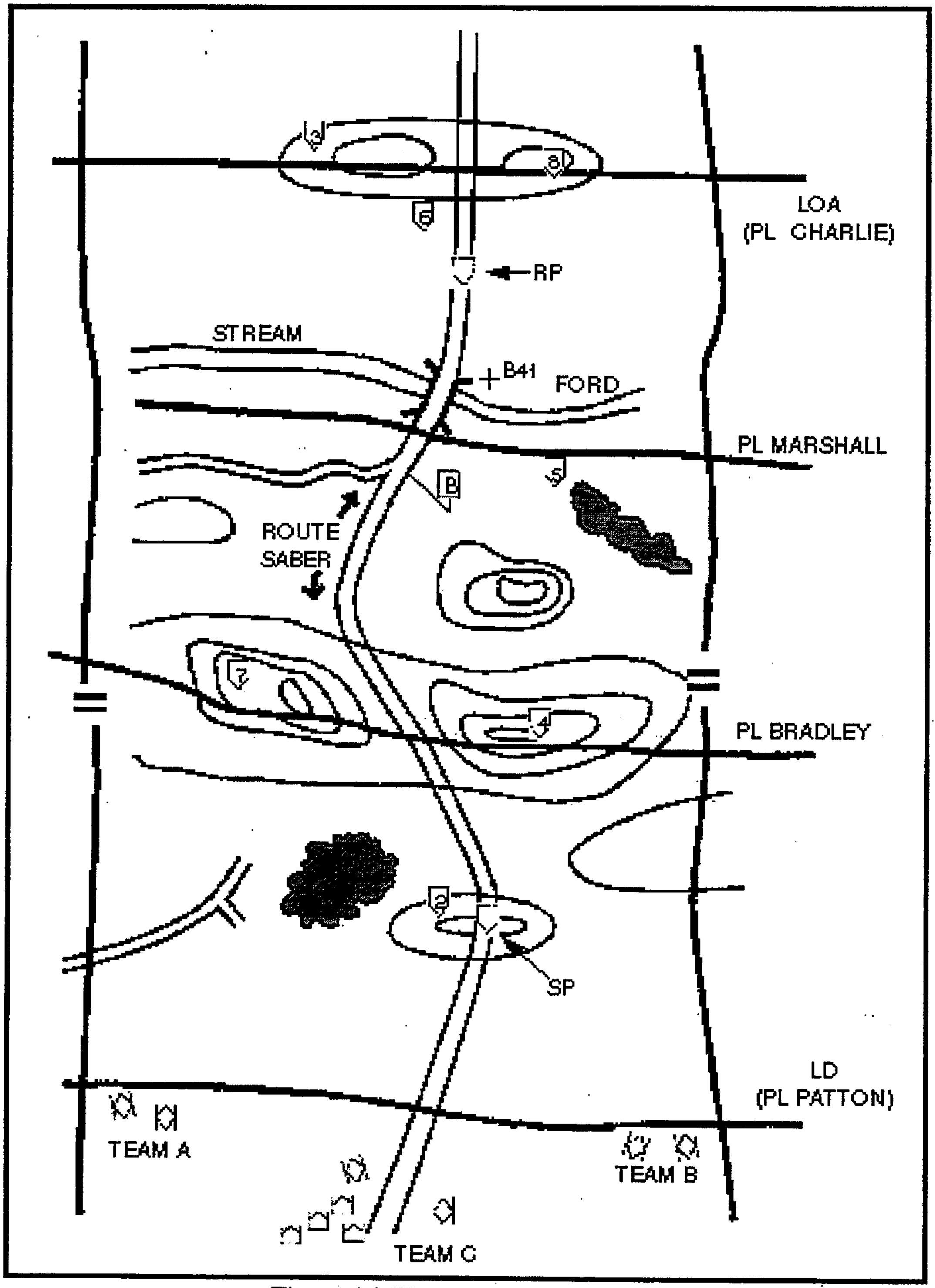

Figure 4.2 Three Team Organization.

C. ENGINEER ROUTE RECONNAISSANCE SCENARIO

1. Scenario Constraints

The scenario was designed to fully demonstrate the capabilities and limitations of the prototype suite of equipment discussed in Chapter III. It will also follow the 12-step implementation also presented in Chapter III. The scenario will direct its focus toward the following critical tasks:

- Determining the route's trafficability.
- Reconning all built-up areas along the route.
- Inspecting and classifying all bridges on the route.
- Locating obstacles along the route.
- Locating bypasses around built-up areas, obstacles, and contaminated areas.
- Reporting route information.

2. Fictional Scenario

a. Background

Recent terrorist attacks against United States embassies have caused all units to be on a heightened alert, not only those units in the effected areas. As a demonstration of force and to ensure adequate security is being provided to the affected countries, several additional units have been deployed to the area. One unit in particular, a Battalion Landing Team (BLT), has recently been deployed to the area to begin a series of tactical exercises. The countries of concern are in the developing nation status, whose infrastructure is adequate in most areas. However, the network of roads is considerably limited in the areas where the Marines will be training. The majority of the country has returned back to normal after the bombings, however, the BLT must remain on constant alert for potential terrorist activities. The BLT is fully staffed for the exercises to ensure complete mission accomplishment. A reinforced combat engineer platoon is the size of unit that normally supports a BLT. The reinforced platoon is the smallest combat engineer unit capable of conducting sustained operations.

b. Mission

The BLT has recently been assigned a mission from higher headquarters, which is only part of a larger operational plan. The BLT's mission is to form a convoy and move their command post (CP) forward to a predetermined location. The unit's objective is to reach the location quickly, in the most direct route, and in a covered and concealed manner. In the formulation of his plans, the BLT commander and his staff will assess possible routes and avenues of approach to reach the objective.

In the assessment of a potential route, the unit commander requested the current intelligence available from the BLT's S-2 officer (intelligence officer). The S-2 officer was able to obtain recent satellite imagery of the area of interest. Evaluation of the satellite imagery revealed two potential options (Figure 4.3).

1. The entire route appears trafficable and appears to be a hard-surface paved road. However, it is not the most direct route and appears appreciably longer than a direct route.

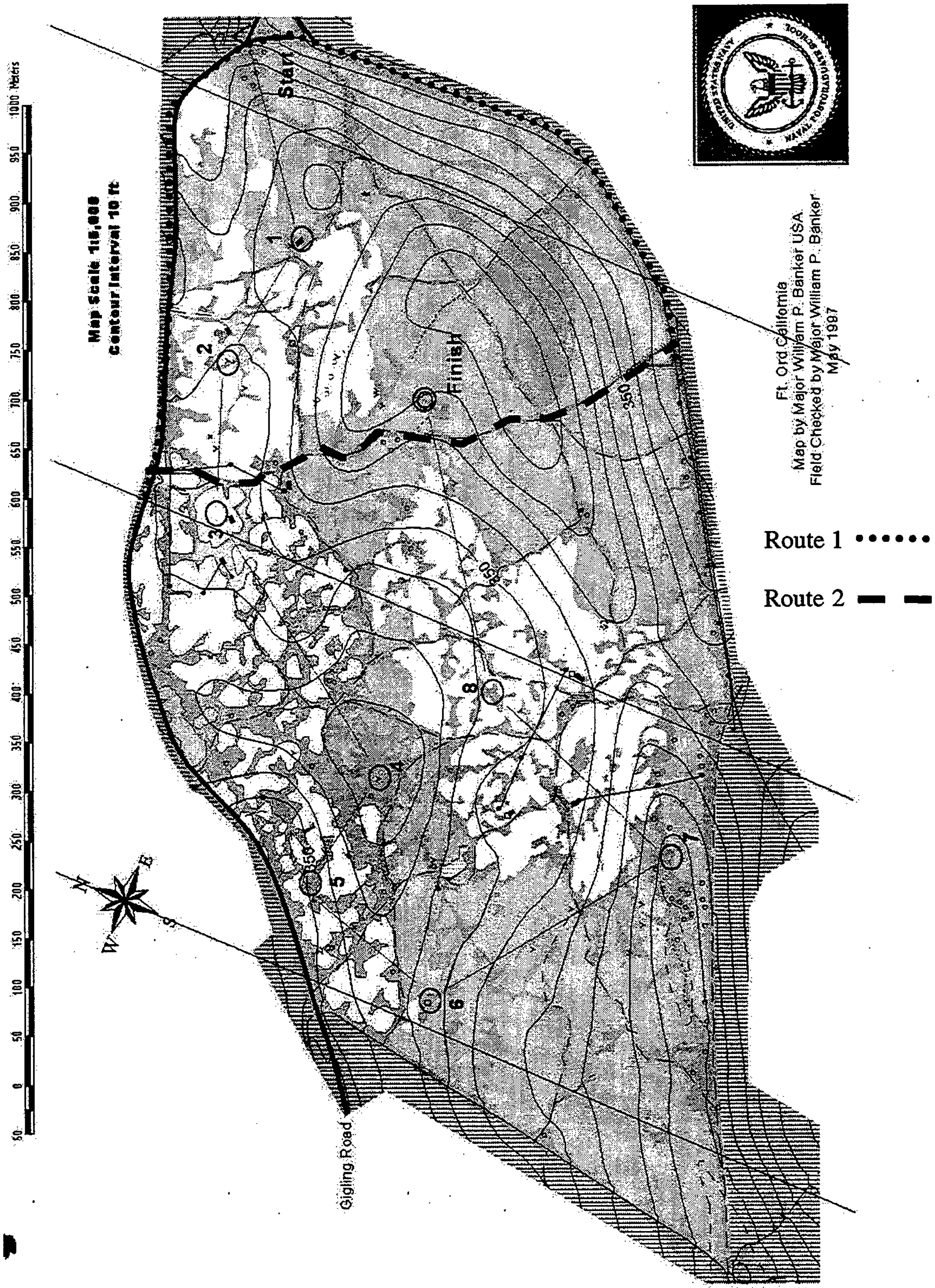

Figure 4.3 Route Reconnaissance Scenario Area Map.

2. The other route appears to be a direct route. However, it appears to be an unpaved road and the trafficability of the route cannot be ascertained from the satellite imagery.

Before the commander issues his orders he will need specific information concerning the trafficability of both potential avenues of approach. The unit commander has decided to use the attached combat engineer platoon to reconnoiter both routes to determine their trafficability. The commander will then use the information provided by an engineer reconnaissance team to decide on a course of action and issue his orders.

c. Route Reconnaissance Mission

The mission will commence after the reconnaissance unit receives an order from the BLT commander specifying the route the platoon must reconnoiter. When the scout platoon (with an engineer platoon) conducts a route reconnaissance, it often deploys in a V formation because of the mission's focused nature. Team A is positioned to the left of the route, Team B to the right, and Team C (with an engineer platoon) in the center of the zone. The platoon should deploy into the formation before reaching the LD, so that it crosses the LD at the specified time. The platoon leader reports crossing the LD when the first element crosses it.

The scout platoon leader is responsible for movement through the zone. He uses checkpoints to control the movement and to focus on obstacles, key terrain, or features that may influence movement along the route. The engineers focus on obstacles that must be located and cleared. Their efforts must focus on a specific PIR (Priority Intelligence Requirement) to ensure that the reconnaissance occurs in a timely manner.

Team C should be positioned along the route so that it can observe the route, and one element of the team must physically drive the entire route. Unless the sector is very small or very open, the platoon will move as individual teams. As the sections move to the checkpoints, they maneuver in a zigzag pattern to clear the sector and accomplish all critical tasks of a route reconnaissance. The lead teams on the flanks must observe the route and report any restrictions or obstacles that may restrict movement along the route. Visually clearing the route before Team C travels along it provides for better security and allows Team C to concentrate on the critical reconnaissance tasks. As the teams maneuver toward the checkpoints, they maintain visual contact with the route.

After both lead teams report "Set" and are in overwatch positions, Team C begins the route reconnaissance. As the platoon leader moves along the route, his wingman maneuvers to provide overwatch for the platoon leader and the engineer platoon. As the engineer platoon leader travels along the route, he is normally required to send a route classification of the trafficability at intervals designated by the commander. A route report may be required only if there is a significant or unexpected change in the route's makeup.

D. SUMMARY

This chapter provided an in-depth discussion of route reconnaissance. It provided a detailed explanation of the process and proposed a possible scenario that would utilize a route reconnaissance mission. It was decided, as a demonstration of the prototype system, to execute a route reconnaissance scenario. However, the concepts and solutions would have been the same for the other two traditional reconnaissance missions: area and zone. This chapter provided the scenario and the groundwork from which the next chapter will build upon. The following chapter will provide the implementation of the route reconnaissance scenario. It will provide the data analysis of the capabilities and limitations of the prototype suite of equipment as applied to the scenario.

V. IMPLEMENTATION AND DATA ANALYSIS

A. INTRODUCTION

> The Marine Corps is looking at change, not as a challenge, but as a series of opportunities. We are doing it with an incoming generation of Marines that is smart, motivated, and has grown up in a climate of explosive change. These young men and women are computer literate. . . they are comfortable with high technology, and are ready to embrace the future. Around these Marines, we have already begun to build a package of capabilities which will make certain that they remain the world's premier crisis response force, and we have only just begun to exploit the possibilities.
>
> General Charles C. Krulak, Commandant of the Marine Corps

A reconnaissance team, as described in the scenario from Chapter IV, conducted a route reconnaissance mission. The team's mission was to identify the trafficability of two potential routes, specifically the non-paved route. The team captured several digital images of the proposed routes and relayed the images and data to the unit commander. In particular, the team captured five different images identifying the trafficability of the non-paved route. The information transmitted from the team assisted the unit commander in his decision-making capability. He was able to quickly assimilate the intelligence gathered from the recon team to make a faster, more informed decision. The commander was able to issue the order, using the graphical data provided by the team, and get the BLT prepared for movement well before the recon team returned from the route reconnaissance mission.

This chapter will provide a graphical step-by-step description of the implementation of the prototype suite of equipment. The implementation will follow the 12-step process described in Chapter III. It will include a description of the process followed by an image. This chapter will provide the analysis of the implementation of the route reconnaissance scenario. Additionally, it will analyze the capabilities and limitations of each component of the prototype suite of equipment. The chapter will conclude with the analysis of the data generated by the prototype.

B. IMPLEMENTATION

1. Initial Preparation for the Scenario

The prototype was designed to be a man-portable solution. It is compact and lightweight, with the intention of not interfering, hindering, or constricting the movements of the Marine. The entire suite of equipment was designed to be carried by an individual Marine, attaching to the Marine's 782 gear (cartridge belt and H-harness). The HPC and digital camera are stored in a pouch attached to the cartridge belt on the Marine's right side. The cellular phone and the GPS are both attached to the shoulder straps of the H-harness--the cellular phone on the left and the GPS on the right. The location of the components were placed to allow maximum flexibility for the Marine and to be as unobtrusive as possible. The location was additionally dictated by the location of the ports on the HPC (Figure 5.1).

Before the HPC could be used for the scenario, it needed to be configured for operation. This entailed configuring the "Remote Networking" for dial-in into a network and "Inbox", the email software, needed to be configured. Both applications were easy to configure via the built-in menus and both were successfully tested prior to the scenario demonstration.

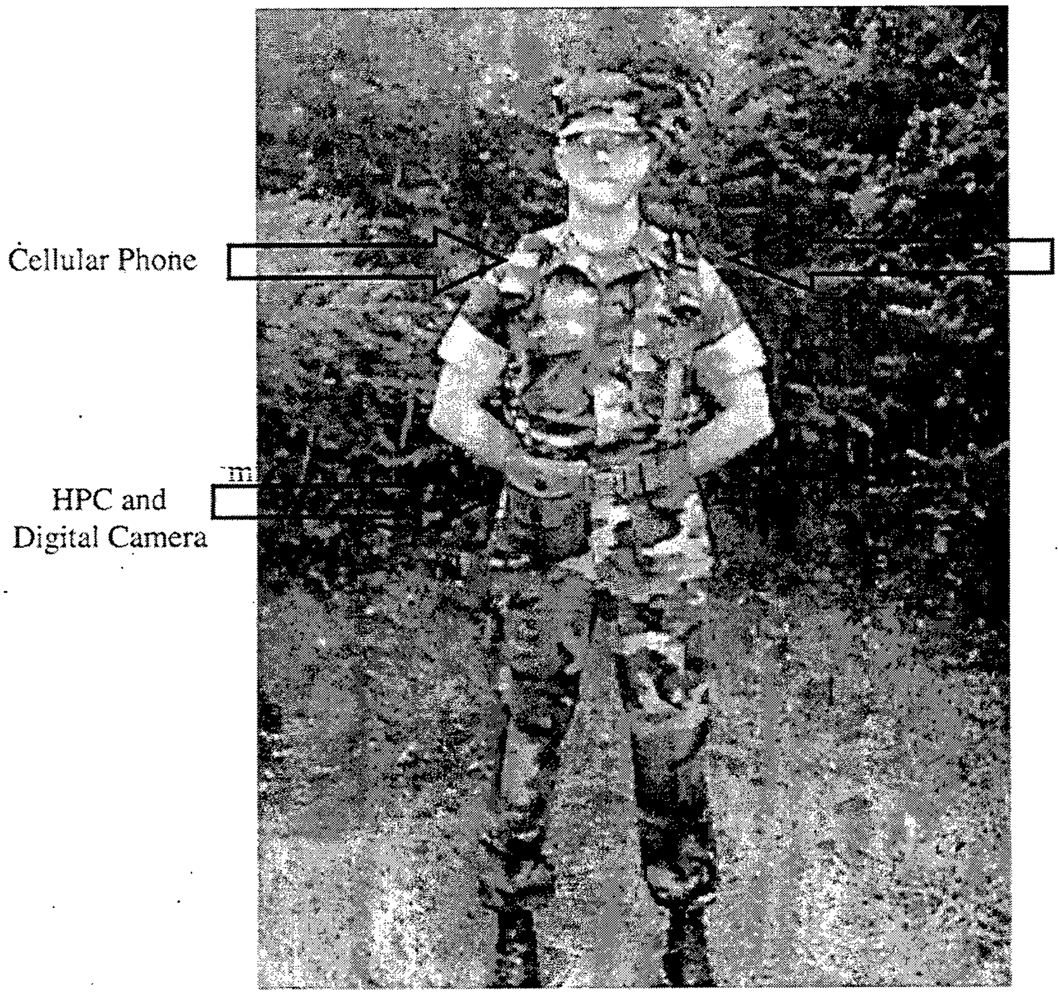

Figure 5.1 Engineer Reconnaissance Prototype.

2. The Order, Movement, and Establishing Communication

After the reconnaissance team has received their mission from the unit commander, they will move to the area of interest--the objective. Upon arrival at the objective, the team will establish communication with the unit commander in the most efficient manner available. In the case of the demonstration, the team used the cellular phone to contact the unit commander (Figure 5.2). At that time, the commander can provide updated intelligence to the team or even change the mission.

Figure 5.2 Establishing Communication using the Cellular Phone.

3. Capture of a Digital Image

The team will digitally capture the objective by taking several images of the area (Figure 5.3). The camera provides the Marine the flexibility to take images of differing resolution and compression. Both the resolution and the compression are options that are manually selected by the Marine. The camera provides two different levels of resolution (1152 x 864 or 640 x 480) and three different levels of compression: good, better, best. Additionally, the Marine can use the zoom capability of the camera to provide different angles or zoom-in/zoom-out on the objective. The Marine is provided immediate feedback from the camera by using its LCD to view the images (Figure 5.4). The Marine can either accept the image or immediately delete the image. If the image is deleted, the Marine can capture another image that may better satisfy the requirement of the mission.

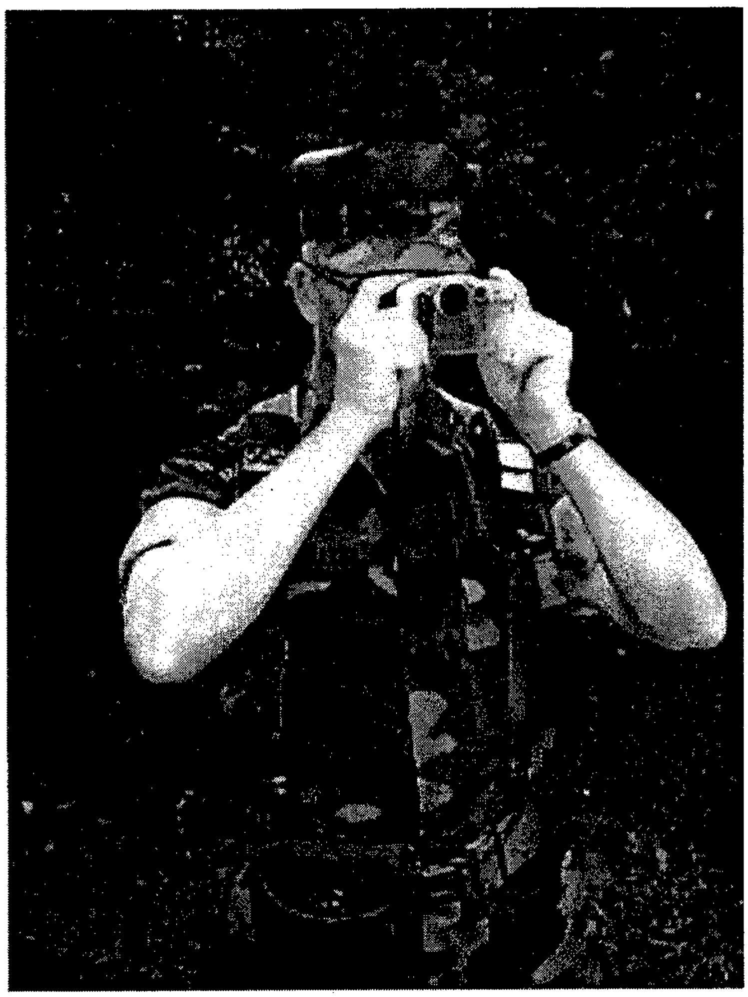

Figure 5.3 Capture of a Digital Image.

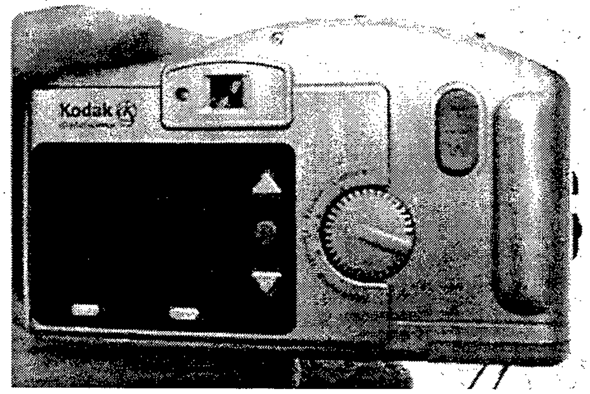

Figure 5.4 Review of the Image.

4. Transfer of the Image to the HPC

The digital camera will store the images to the compact flash memory card. The 4MB flash memory card included with the camera can store up to 16 of the highest quality images or a maximum of 60 images of lesser quality. The compact flash memory card will be removed from the digital camera (Figure 5.5) and reinserted into the flash memory slot on the side of the HPC (Figure 5.6). Once the HPC is powered on, a new folder is created called "Storage Card" and the transfer of the images is complete. The HPC is capable of identifying the images on the flash memory card as JPEG images, but is not able to view the images. The reason for this is because the HPC did not come equipped with the appropriate software to view JPEG images.

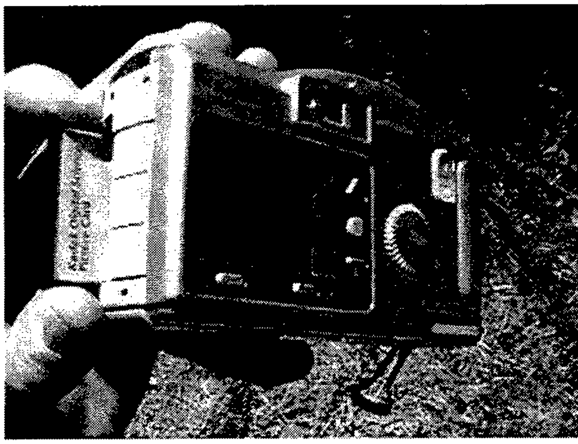

Figure 5.5 Removal of the Card.

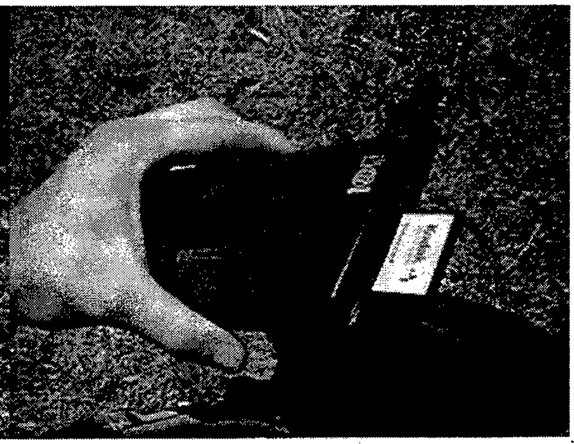

Figure 5.6 Inserting the Card.

5. Capture of the Latitude, Longitude, and Bearing

The latitude, longitude, and bearing are then cross-referenced to the recently captured image. The GPS program will be initiated on the HPC by double tapping the GPS icon. The program displays a map with the team's current location designated by a circle with an arrow indicating direction or bearing. The Marine retrieves the latitude, longitude, and bearing by selecting the "View" option on the main menu bar. The "View Status" option will then be selected from the drop-down menu. The "View Status" provides the Marine the latitude, longitude, and bearing from the GPS, which will be manually cross-referenced to the image.

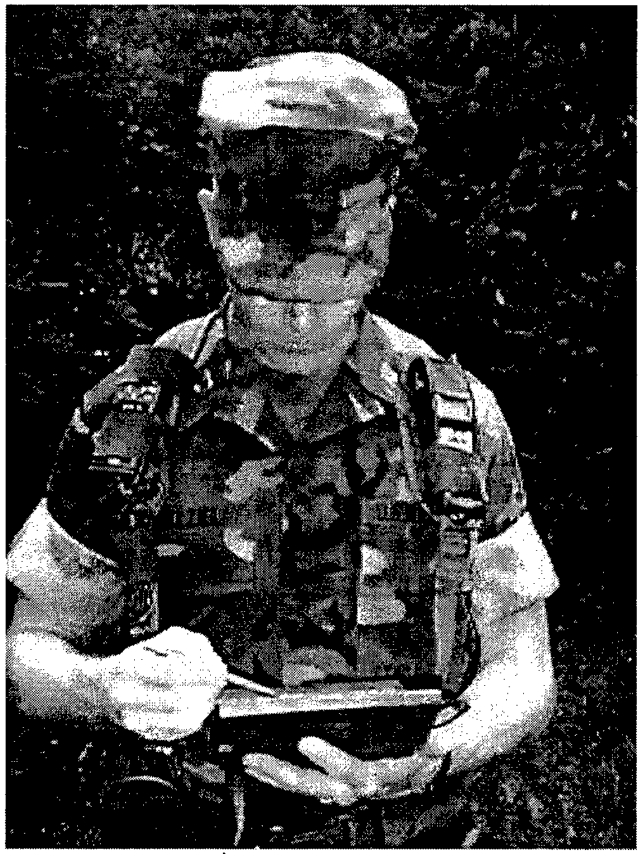

Figure 5.7 Capture of GPS Coordinates.

6. Development of the Email Message

An email message will then be created which will contain the latitude, longitude, and bearing and the image will be included as an attachment to the email. The email program will be initiated on the HPC by double tapping the "Inbox" icon. The Marine will select the "Compose" option on the main menu bar. The "New Message" option will then be selected from the drop-down menu and the Marine can begin composing the message (Figure 5.8). The body of the email will contain any pertinent information about the objective and also include the latitude, longitude, and bearing (Figure 5.9). Finally, the image will be appended to the message as an attachment before the email is transmitted. Each image will be transmitted individually, therefore an email message will be developed for every image.

Figure 5.8 Composing an email message.

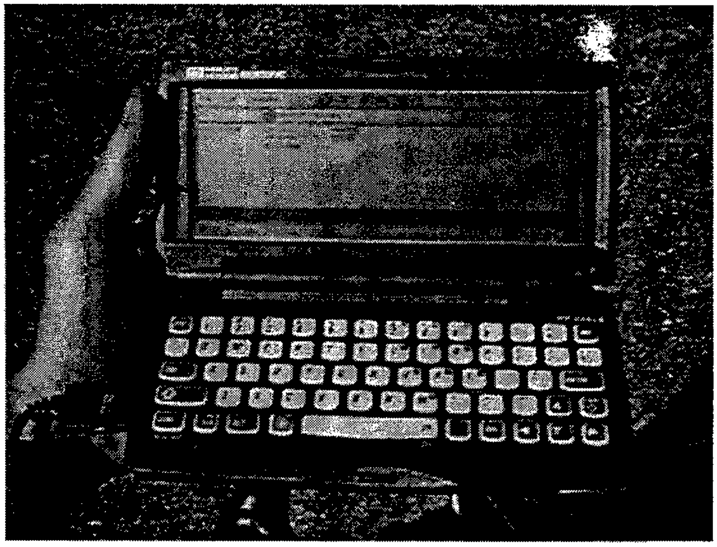

Figure 5.9 Screen Capture of an Email Message.

7. Transmission of the Email with Attachment

The email will then be transmitted wirelessly to the unit commander. The Marine will select "File" from the main menu bar and select "Send" from the drop-down menu. However, this does not send the message. The Marine must select "Service" from the main menu bar and select "Connect" from the drop-down menu to initiate the transmission of the email. The selection of the "Connect" option will generate the pop-up menu "Dial-Up Connection". The Marine must then tap the "Connect" button to begin the transmission. The remainder of the process is automated and needs no further action from the Marine. The HPC sends the necessary commands to the cellular phone via the PC-card modem to begin dialing. Once the connection has been established with the network, "Inbox" will first check for any incoming messages and then transfer any outgoing messages.

8. Receipt and Interpretation of the Email

The email message with attachment will be received and interpreted by the unit commander. The unit commander will be logged into his email account and the account will be monitored continuously for incoming messages. Upon receipt of a message from the reconnaissance team, the text of the message will be interpreted and the image downloaded for additional processing. The latitude, longitude, and bearing will be cross-referenced to a map and the position of the images will be indicated on the map.

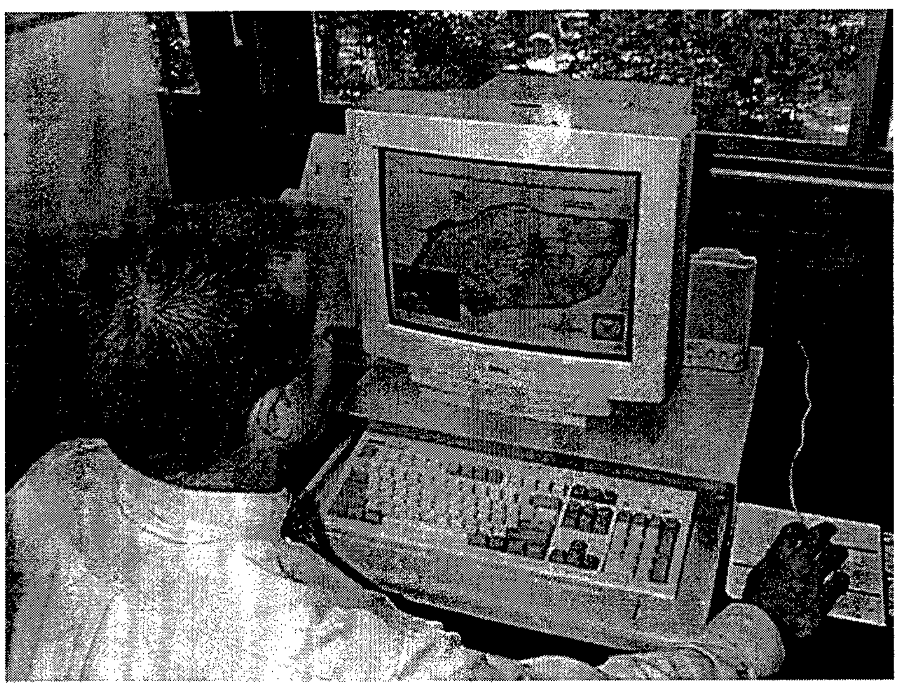

Figure 5.10 Image of the emailed image retrieved on a personal computer.

C. DATA ANALYSIS

1. Image sizes and Transmission times

a. Image #1:

Latitude N 36.6454 Bearing: 159.90
Longitude W 121.7668

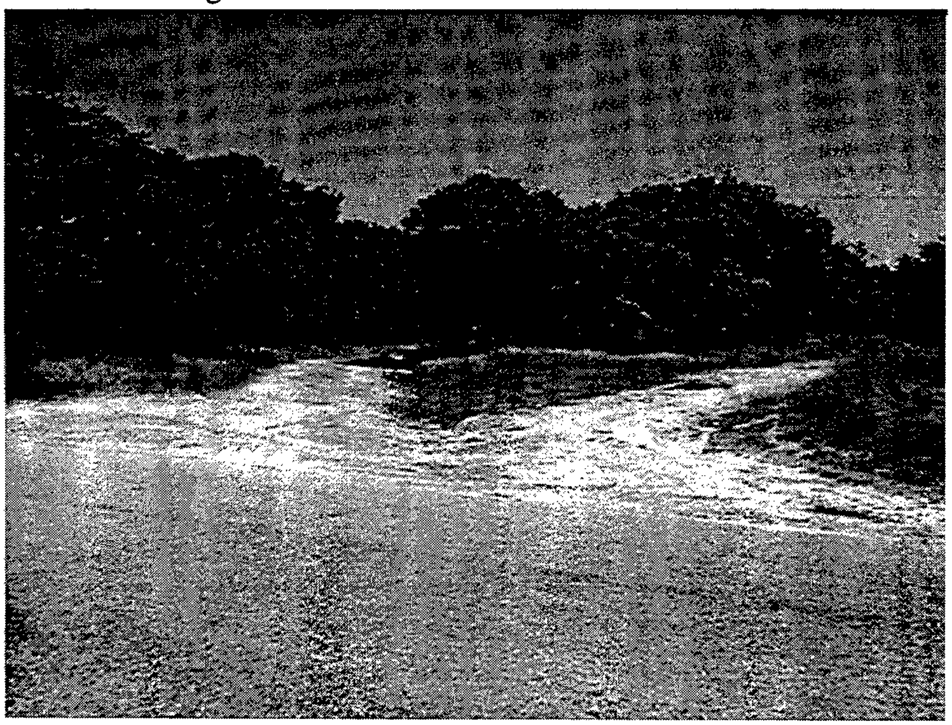

Figure 5.11 Image #1.

Resolution	Compression	Image Size	Transmission Time
1152 x 864	Good	87.4 KB	5:00
	Better	146 KB	6:25
	Best	230 KB	8:40
640 x 480	Good	45.2 KB	2:40
	Better	70.5 KB	3:05
	Best	102 KB	4:20

TABLE 5.1 IMAGE #1 (SIZE AND TRANSMISSION TIMES).

b. Image #2:

Latitude N 36.6419
Longitude W 121.7662

Bearing: 155.70

Figure 5.12 Image #2.

Resolution	Compression	Image Size	Transmission Time
1152 x 864	Good	121 KB	4:50
	Better	197 KB	7:35
	Best	295 KB	10:00
640 x 480	Good	60 KB	2:45
	Better	98.1 KB	4:25
	Best	137 KB	7:30

TABLE 5.2 IMAGE #2 (SIZE AND TRANSMISSION TIMES).

c. Image #3:

Latitude N 36.6413 Bearing: 195.30
Longitude W 121.7669

Figure 5.13 Image #3.

Resolution	**Compression**	**Image Size**	**Transmission Time**
1152 x 864	Good	115 KB	4:50
	Better	181 KB	7:30
	Best	274 KB	8:55
640 x 480	Good	56.2 KB	2:30
	Better	88.8 KB	3:20
	Best	128 KB	5:35

TABLE 5.3 IMAGE #3 (SIZE AND TRANSMISSION TIMES).

d. Summary

It is apparent from the tables that the higher the resolution, the larger the image size. The "High" resolution (1152 x 864) is almost double the size of the "Standard" resolution (640 x 480) which equates to almost double the time to transmit the file. Image size, and consequently transmission time, need to be addressed to extend the battery life of all components, especially the HPC. (Battery life is discussed in the next section.) Chapter III presented the minimum requirements and capabilities for the digital camera. One of the capabilities stated, "It must have the ability of varying resolution, with maximum resolution greater than 640 x 480. The greater resolution allows images to be taken with greater detail." This capability provides the unit commander the flexibility to request images of varying resolution. However, the price is lengthy transmission times. The image size and transmission time of the "High" resolution (1152 x 864) is impractical for this battery powered prototype solution. The "Standard" resolution (640 x 480) using "Best" compression provides the optimal combination of image size versus image detail.

2. Battery Life

Battery life was a major concern during the testing because all of the components are battery powered. The issue became: How long can the prototype operate before battery failure occurred? An offset to the battery life problem was rechargeable batteries. Both the cellular phone and the HPC had the capability of recharging their own batteries, which proved to be an enormous saving.

Even though the GPS, digital camera, and cellular phone were battery powered, none of the component's battery life ever became an issue. The GPS requires 4 AA batteries for proper operation. Its power consumption is rated at 1 watt and the expected battery life of the GPS is 12 hours. The battery life of the GPS exceeded 12 hours and performed adequately throughout the entire test. The digital camera also requires 4 AA batteries. The battery life of the digital camera did not exceed that of the GPS, but it did take over 50 images before the batteries needed to be replaced. The battery life of the cellular phone never became an issue, but is estimated to be 12 hours per charge. The main reason is that it exceeded the battery life of the HPC by almost ten times. Another advantage of the cellular phone was that it came equipped with a rechargeable battery.

The HPC had the most difficulty of all the components when it came to battery life. The HPC only requires 2 AA batteries for proper operation. The HPC's expected battery life during normal operation is 15 hours. However, the addition of the compact flash memory card and use of the serial port for the GPS reduced the battery life from 15 to approximately six hours. But the main power consumption came from the addition of the PC-card modem. The PC-card modem drastically reduced the HPC's battery life from six hours to approximately one hour.

Therefore, because of the HPC's battery life constraint, the prototype could only operate continually for one hour before battery failure occurred. However, it was possible to transmit six images during the one hour period of time, which ensured the success of the route reconnaissance scenario.

D. SUMMARY

The implementation of the prototype suite of equipment into the route reconnaissance scenario was a success. Digital images could be captured, transferred to a handheld computer, cross-referenced with GPS coordinates, and transmitted via email to a distant source. All of the components interfaced and performed as expected.

The chapter provided a description and a graphic depiction of the implementation of the prototype in actual use. The demonstration revealed that the prototype met the criteria of being lightweight and man-portable. The entire suite is capable of being carried by an individual Marine, connected to his cartridge belt and H-harness.

The analysis of the data uncovered two main issues: image size and battery life. Both issues are interrelated, with the life of the batteries being dependent upon the image size. Image size is directly proportional to the resolution and compression used in capturing the image. The minimum requirements and capabilities required the camera to have a varying resolution greater than 640 x 480. However, images greater than 640 x 480 greatly reduced the battery life through lengthy transmission times. Consequently, this also reduced the number of images the prototype could deliver. To take full advantage of the limited resources (one hour of battery life), the prototype should capture images at "Standard" resolution (640 x 480) using the "Best" compression. This would provide the optimal combination of image size versus detail, thus providing the capability of sending enough data to accomplish the mission.

The following chapter will address future applications of the prototype. It will also discuss certain issues the military would need to address before the prototype could be implemented. Finally, the chapter will provide recommendations for the future and the possibilities for future research.

VI. RECOMMENDATIONS

A. INTRODUCTION

The purpose of this chapter is to analyze current technologies and to provide recommendations for the future. This thesis researched the feasibility of developing and implementing a prototype suite of equipment.

The prototype proposed a solution to automate the engineer reconnaissance reporting process through the use of digital imagery and wireless communication. It also proposed a solution that leveraged current COTS technologies. This chapter will look beyond the research accomplished by this thesis and discuss possible improvements to the prototype that may already exist or are on the near horizon. It will also address areas of concern if the prototype were to be fully implemented by the military. Finally, this chapter will also highlight possible areas of future or follow-up research.

B. IMPROVEMENTS TO THE PROTOTYPE

Technological improvements are occuring at a phenomenal pace--the processing power of the personal computer is literally doubling about every 18 months. The requirements for the prototype were generated during the last quarter of 1997 and evolved into the criteria for the minimum requirements and into individual components during the first quarter of 1998. Since the components for the prototype were decided upon, several technological advancements have become available that could improve the prototype and the process.

1. Technological Advances

Technological advances have already occurred in several areas that could improve the process. Recent software releases for the HPC provide added functionality in imagery and the GPS. Sierra Imaging Inc. has developed a new imaging application, Image Expert CE, for WinCE which allows images from a digital camera to be viewed on the HPC. This capability was unavailable with the current prototype. The current release of the GPS software allows email to be sent from within the GPS program. This feature further automates the process of sending latitude, longitude, and bearing. Finally, advances in battery technology have extended the expected battery life by almost ten times. The extended battery life would make the prototype a more viable solution.

2. Integration of Components

Improvement to the prototype could also be achieved through tighter integration of components. Devices are already available that incorporate at least two of the components from the prototype into one. Nokia is one of the manufacturers that have combined the technologies of the cellular phone with the HPC. Presently the functionality of Nokia's HPC is inferior to the HP360LX. It provides only information in a textual format and has limited additional communications ports. Another example is the combination of a digital camera and a HPC. Again, however, the integration of these components provides a decrease of functionality. The digital camera is incorporated into a PC-card, thereby reducing the flexibility of the HPC. The PC-card camera does not provide the same capabilities of the Kodak DC210. Finally, HPC's are also being designed with built-in modems. This integration would eliminate the need for the PC-card modem and the associated reduction of battery life caused by a PC-card modem. However, presently the built-in modems are not cellular phone capable.

The following have provided examples of technological advances which have integrated at least two of the components of the prototype. The three examples display the possibilities of integration for the future.

3. Automation of the Process

The previous two sections provided examples of existing technological advances. This section will address potential advances that could automate the engineer reconnaissance reporting process. Automation could be implemented through hardware or software. A hardware solution would be a more functional integration of the prototype components. The HPC would remain the center of the prototype providing the necessary processing. A hardware solution that would leverage future COTS technologies would be the integration of a built-in cellular modem and a fully functional PC-card camera. This future prototype would produce a more compact solution and reduce the amount of necessary human intervention.

However, a more complete automation of the process could be realized through software. Software is already available that integrates the GPS, email, and the HPC. The next logical step would be a program that fully automates the process through the incorporation of the digital camera. The program would be a device manager whose main purpose would be to monitor the status of all the components and initiate a series of steps upon receipt of an instruction from the HPC. The following describes how the automation could be implemented using software.

After an image is captured by the digital camera, it is viewed on the HPC. Acceptance and storage of the image by a Marine would initiate the program. The program would interface with the GPS software to obtain the latitude, longitude, and bearing. It would incorporate this data into the body of the email message and attach the image to the email. The program would then wirelessly connect to the network and transmit the information. The implementation of this program would eliminate the majority of the human intervention presently necessary with the current prototype.

C. MILITARY IMPLEMENTATION CONCERNS

Before the prototype could be implemented for military use, several key issues must be addressed. The following areas were recognized as concerns, however they were beyond the scope of this thesis.

1. Security

The imagery and textual information being transmitted by the reconnaissance team are generally considered to be classified and should be protected. The team is transmitting critical information about the enemy and their exact location in latitude, longitude, and bearing. Security could be provided using end-to-end or link encryption. With end-to-end encryption (sometimes called off-line encryption) a message is encrypted when it is transmitted and is decrypted when it is received. The network may not even need to be aware that the message is encrypted. The message remains encrypted through the entire communications process. With link encryption (sometimes called online encryption), the encryption is performed just before the message is physically transmitted. Link encryption is typically invisible to the user; it is simply part of the transmission process. [Russell and Gangemi, 1992] Either method could be used to provide protection to the data even if the message was intercepted by the enemy.

2. Ruggedization

The components used for the prototype were COTS equipment. To provide a reliable solution for the military, the components would need some form of additional protection from the environment and other elements. Ruggedization could entail the hardening of every component. Each component could be ruggedized to meet the stringent requirements of the military. However, this would significantly increase the weight and cost of the suite of equipment. It may no longer be a lightweight, low cost solution. Ruggedization could also be as simple as a protective carrying case. The hardened case would surround the components, protecting them from the environment without constricting the Marine's movements.

3. Communication Footprint

The communications equipment used by the prototype was a cellular phone, whose coverage can be limited depending upon the operating environment. The communications equipment required for an actual application would need to provide the capability of providing some form of encryption, as mentioned in the previous section. It would also need to provide widespread coverage.

The communications equipment would need to be versatile enough to provide the distance required of the reconnaissance team, provide sufficient bandwidth for the transmission of imagery, and finally, encryption for adequate security.

4. Integration into Existing Information Systems

For the prototype to be accepted as a valuable tool for the unit commander, it must be seamlessly integrated into the existing information systems currently being used by the military. The military does not need another stove-pipe solution. The information delivered by the reconnaissance team must be capable of being integrated into existing information systems. For example, the information could be sent as an OTH-Gold (Over the Horizon) message format to be interpreted and displayed by the Global Command and Control System (GCCS). GCCS is the current command and control information system being used throughout the Department of Defense. The information would then be in a usable format that could be viewed by anyone having access to a GCCS terminal. The data could then be further processed and integrated into the overall strategic plan.

D. FUTURE RESEARCH

1. Engineer Reconnaissance Reports

This research discussed only the imagery portion of the engineer reconnaissance reporting process. Another research opportunity would be the automation of the entire reporting process. The engineer reconnaissance forms could be recreated electronically and made accessible to the reconnaissance teams via the Internet. The forms could then be accessed and completed by the teams over the Internet. The information would reside on a central database repository for retrieval and viewing by multiple users.

2. Intelligence Gathering

This research proposed a solution for engineer reconnaissance, but would the prototype be applicable to general military intelligence gathering or other reconnaissance missions? A new analysis of the requirements could be accomplished to determine the feasibility and the application of this type of prototype to other military situations.

3. Full Motion Video

Finally, another research opportunity that could be pursued would be the progression from using still images to using full motion video. Reanalysis of the requirements could be performed to determine what additional benefit could be achieved through the development and implementation of a suite of equipment capable of producing full motion video. This research could serve as a template in determining the minimum requirements and selection of a suite of equipment that would satisfy the additional functionality.

E. SUMMARY

This research developed and implemented a prototype suite of equipment to automate the imagery portion of the engineer reconnaissance reporting process. The test of the prototype in a fictional route reconnaissance scenario was a success. However, this research should not end with the one success. Advances in technology will continue to provide new capabilities and additional functionality that will only enhance the performance of this prototype. This chapter concluded with several different research opportunities which could be pursued to further implement the use of digital imagery into the military.

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