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Feasibility analysis of using microcircuit technology in logistics applications/radio frequency (MITLA/RF) to support equipment maintenance management

Amirante, Robert V.

Monterey, California. Naval Postgraduate School

NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

FEASIBILITY ANALYSIS OF USING MICROCIRCUIT TECHNOLOGY IN LOGISTICS APPLICATIONS/RADIO FREQUENCY (MITLA/RF) TO SUPPORT EQUIPMENT MAINTENANCE MANAGEMENT

by

Robert V. Amirante
and
Greggory L. Baker

December, 1993

Thesis Co-Advisor: Keembom Kang
Thesis Co-Advisor: Jeffrey Nevels

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by

Robert V. Amirante
Major, United States Marine Corps
B.A., George Williams College

and

Greggory L. Baker
Captain, United States Marine Corps
B.A., University of Florida

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December 1993

Authors: [redacted]

Robert V. Amirante

[redacted]

Greggory L. Baker

Approved by: [redacted]

Keebom Kang, Thesis Co-Advisor

[redacted]

Jeffrey Nevels, Thesis Co-Advisor

[redacted]

David R. Whipple, Chairman
Department of Administrative Sciences

ABSTRACT

This thesis presents the background, criteria, and baseline recommendations for a Microcircuit Technology in Logistics Application/Radio Frequency (MITLA/RF) proposal to support developing maintenance management doctrine. Its main thrust is a preliminary feasibility analysis of MITLA/RF to identify key issues with regard to maintenance operations within emerging Operational Maneuver From The Sea (OMFTS) concepts. This thesis surveys current requirements, information systems initiatives, test/evaluation results, implementation issues, and technology tradeoffs. It offers alternatives to reliance on manual record keeping and frameworks for enhancing horizontal/vertical information flows, explores several near real-time interactive decision making tools, and suggests doctrinal improvements through a fusion of procedural and high-tech approaches. This study is an outline for melding policy change with the state-of-the-art technology required to successfully support emerging Combat Service Support (CSS) operations.

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I. INTRODUCTION

A. OVERVIEW

As stated clearly in " . . . From the Sea," a Navy and Marine Corps White Paper that articulates the new direction for the Naval Service, the Navy and Marine Corps team will provide the nation's Naval expeditionary forces – shaped for joint operations – operating forward from the sea – tailored for national needs. This new direction for the Naval service means that the Marine Corps must continue to improve its rapid response capability. The primary objectives outlined in Marine Corps' Exploratory Development Program FY 1993 Block Plan contribute to this goal. Specifically, the focus of this Block is to develop/demonstrate technologies to meet the Marine Corps' unique responsibility for expeditionary missions, amphibious warfare, and subsequent operations ashore. Expeditionary operations, amphibious in nature, place a premium on mobility, command and control responsiveness, and global (near real-time) communications.

Combat Service Support (CSS), as currently defined, is not optimally designed to sustain combat elements where increased operational tempo, mobility, and over-the-horizon maneuver warfare have outraced the development of logistic systems. Accordingly, we need to redefine Combat Service

Support concepts and identify ways to improve Marine Air Ground Task Force (MAGTF) operational effectiveness through:

- Reducing labor requirements
- Expanding the flexibility of CSS operations
- Providing near-real time, worldwide access to data
- Enhancing the capability inherent in the CSS concept
- Using current hardware and software to the maximum extent possible
- Developing/demonstrating technologies that will allow CSS organizations to support emerging MAGTF operational ideas beyond the year 2010
- Providing these capabilities to the Fleet Marine Force with the least risk and maximum timeliness

New technologies are required to quickly process unprecedented quantities of CSS data to support the logistics aspects of emerging command and control concepts. Experience during Operation Desert Storm serves as a valuable object lesson for the need for automated systems to support Marine Corps operations. The potential utility of a deployable system that locates assets and updates CSS systems with a minimum of labor is unlimited. Regional Information Systems Management Offices (ISMO) and logistics personnel developed ad hoc database programs during the operation; these were simple and quick attempts to manage overwhelming problems. Although providing only crude data processing support, they proved to be tremendously useful in managing the substantial volume of data.

These limited successes suggest that proper application of technology and systems integration would greatly affect the Marine Corps' capability to perform its missions.

Several CSS functions will require new or substantially improved data processing capability. Decision making, hindered by disjointed, incomplete, and cumbersome records/forms/messages, can no longer be tolerated. The ability to locate and use information regarding such key ideas as equipment maintenance posture (operational availability) and periodic maintenance/combat repair are prime examples of CSS functions that must embrace developing technologies.

Currently, equipment maintenance management is a labor intensive paper and menu-driven process that receives little attention during contingency scenarios – exactly when this information and CSS flexibility are most critical. The various automated "systems" locally developed by Marine Corps activities to track some limited maintenance functions are not standardized, often insupportable, lack connectivity, and result in essentially manual systems without paper. For maintenance support to be responsive, new technologies are needed to enhance horizontal/vertical information flow and to provide interactive decision making tools.

To track maintenance management, two levels of the CSS system are fundamental. The first level is oriented toward a global perspective, where Fleet Marine Forces (FMF) are concerned with equipment requirements, locations, and their operational availability. The second level is a local view including battalion maintenance commodities, Combat Service Support Elements (CSSE), Arrival and Assembly Support Parties (AASP), or Logistics Movement Control Centers (LMCC) where tracking equipment in marshalling areas and maintenance activities is a key objective. A global view requires periodic updates of information, often within hours. A local view requires near real-time flow of information, often within minutes. The appropriate integration of systems and technologies will meld these levels, streamlining equipment maintenance management procedures and improving Marine Corps readiness.

Solving the problem of the need for fully automated, near real-time data will require systems that involve developing and integrating emerging technologies such as: (1) micro chips (smart tags), (2) extremely small, low power, long shelf-life batteries, (3) technologies for transmitting data over-the-horizon, and (4) new electronic methods to query, queue, and receive data from smart technology.[1] New information manage-

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[1] Their "intelligence" stems from concepts that envision their communicating with future logistics systems, knowing where they are, and self-diagnostic maintenance status.

ment approaches must meet the technical challenges of adapting to greatly expanded volumes of data and wide area networking in a wireless environment, particularly when data transfer must be secure.

To execute sound and timely decisions, commanding officers and maintenance officers require accurate, consistent data about equipment status. The first step in this information gathering process is to actively monitor equipment maintenance management. Recent advances in data-recording technology offer the opportunity to examine ways to improve existing manual systems that are error-prone, rely on "hard copy" documentation, and require repetitive data entry. An automatic identification system will facilitate decision making and improve data collection precision, while decreasing the costs associated with gathering and maintaining such data.

The Department of Defense (DOD), during the past several years, has been conducting a program to reduce the generation of and reliance on manually-prepared technical documentation. The emphasis has been placed on exploiting advances in many forms of automation technology to reach this objective. Several initiatives show promise of significantly reducing the paperwork and menu-driven keystrokes now associated with our logistics operations. If adopted, such modernization and automation will result in better support to the operating forces. Barcoding and smart tags [contact/near contact and radio frequency (RF)] are indicative of these advancements.

The emergence of microchip tags employing radio carrier waves to receive/transmit data is just beginning to be recognized as a promising logistics tool. Specifically, microcircuit technology has come to the forefront in recent years as a relief from the burdens of manual record keeping. Additionally, it is a value-added concept that allows for intelligent, near real-time communications. It offers the advantage of recording and storing data reliably and eliminates the need to enter the same data time and again. As with other recent advances in data handling, commercially available (off-the-shelf) RF microchip technology is a prime candidate for reducing labor intensity and compartmentalized logistics functions. It is this innovative concept, known as "Microcircuit Technology in Logistics Applications/Radio Frequency (MITLA/RF)," which is addressed by this treatise.

This thesis examines the background, requirements, and baseline recommendations for maintenance management MITLA/RF initiatives. If adopted, such Recording and Tracking Technologies (RTT) will result in an integrated system of computer-aided tools for logistics data processing, information presentation, planning development, and wide-area data transfer to satisfy command and control requirements.

Developing this system allows rapid identification of equipment availability and maintenance status, full automation of the maintenance management process, and informed, strategic decision making. In short, this system will provide CSS the *firepower* required to support Operational Maneuver From The Sea (OMFTS) as envisioned beyond the year 2010.

B. RESEARCH OBJECTIVES

The main objective of this thesis is to answer the primary question, "What is the potential for MITLA/RF to enhance USMC equipment maintenance management operations and to significantly improve force preparedness?" Efforts will focus on the following elements:

- Can it provide near real-time data access?
- What are potential labor and data management savings?
- Will it integrate with and capitalize on existing hardware/software systems?
- Is it compatible with hazardous materials (i.e., ammunition, explosives, fuels, etc.)?
- To what extent will it speed front-end processing of routine maintenance management transactions?
- How well suited is it to storing and reflecting the maintenance status of principal end-items (PEI)?
- Is the application technically feasible and available to satisfy maintenance requirements? For example:
    - Speed – read/write throughput
    - Capacity – initial and future needs
    - Programmability – read only or read/write
    - Service Life – ruggedness and battery life

- Range – reliability as a function of distance
- Reliability – percentage of correct reads and up-time as a function of component failure

C. SCOPE, LIMITATIONS, AND ASSUMPTIONS

1. Scope

The main thrust of this study is a preliminary feasibility analysis of MITLA/RF to identify key issues concerning potential application with specific regard to equipment modification and general maintenance management operations. This thesis surveys: (1) current requirements, (2) technology tradeoffs, (3) functionality, (4) implementation/training issues, (5) test/evaluation results, and (6) "interface-related" initiatives [i.e., capability to link with LOGAIS (Logistics Automated Information Systems, which integrate the functional areas of embarkation, supply, planning, and transportation)]. Both qualitative and quantitative logistics effectiveness factors are examined in support of increased productivity, organizational improvements, and potential cost savings.

This thesis does not explore: (1) life-cycle cost analysis, (2) detailed engineering specifications, (3) material management, (4) provisioning and acquisition of MITLA/RF and logistic support elements, (5) market analysis, (6) system maintenance concepts, and (7) system retirement and recycling.

2. Limitations

The breadth of this study has been constrained by several factors:

- Limited access to substantial "real world" data
- No USMC baseline for aggregate labor hours/costs expended in managing equipment maintenance programs
- Inability to measure tangible value of MITLA/RF to support maintenance operations (i.e., forms/records not translated into supportive software, hardware unavailable for testing, controlled environment to weigh tradeoffs between status quo and emerging technologies, etc.)

3. Assumptions

As technology expands and requirements change, the Marine Corps must have an automated process that is cost efficient, reliable, and acceptable to open systems concepts. In this regard, the following assumptions are offered:

- The learning curve will not be prohibitive.
- It reduces maintenance management costs.
- Through integration with MAGTF II/LOGAIS, the system provides aggregate data from the small unit level up through the joint command level.
- Long-range objectives will consider MITLA/RF technology as a reliable enhancement to emerging LOGAIS systems and compatible with open interactive systems concepts (vice simple automation of paper).

D. METHODOLOGY

Research material was primarily collected from a literature review of:

- Ames and Associates, Aurora, Colorado
- SAVI Technology, Palo Alto, California

- David Taylor Research Center, Bethesda, Maryland.
- Dudley Knox Library, Naval Postgraduate School, Monterey, California.
- War Fighting Systems Branch, Marine Corps Logistics Base, Albany (MCLB Albany), Georgia.
- Logistics Information Systems Branch, Installation & Logistics Branch (I&L), HQMC, Washington, D.C.
- Field Logistics Systems Division, Naval Civil Engineering Laboratory (NCEL), Port Hueneme, California.
- Defense Logistics Studies Information Exchange, U.S. Army Logistics Management Center, Fort Lee, Virginia.

Research techniques used during the study provided a balanced, objective, and comprehensive perspective of the topic. First, the authors' knowledge of USMC maintenance management shortcomings and opportunities, gained over 19 collective years of logistics service, was the catalyst. Using this experience as a spring board, field research conducted with the First Marine Division, First Marine Expeditionary Force (I MEF), Fleet Marine Force, Pacific (FMFPAC) allowed the authors to observe first hand current maintenance management processes, pressing concerns, and future expectations.

Second, extensive meetings with key representatives from NCEL's RTT Group and SAVI Technology were principal sources for research and development (R&D) initiatives. Concerning NCEL, several visits capitalized on the laboratory's ongoing Failure Mode, Effects, and Criticality Analysis (FMECA) seminar. Further, the tour of SAVI's Palo Alto facility provided the authors an introduction to evolving MITLA/RF hardware, software, and global communications projects.

Third, opinion research through personal, telephonic, and printed surveys was conducted with project leaders at I&L, MCLB Albany, and various MITLA/RF vendors. Printed surveys were distributed to various I MEF units and to participants of the USMC Maintenance Management Conference, 10 - 13 August, 1993, Little Creek Naval Amphibious Base, Norfolk, Virginia.

E. THESIS ORGANIZATION

This chapter provides an introduction to a course of action that allows the Corps to bridge the chasm between how we do business today (manual, paper, segregated), and how we must do business beyond the year 2010 (automated, interactive, global). The remaining chapters explore and attempt to answer the primary questions raised in section I.B (Research Objectives). Chapter II describes the status quo, standard policies and procedures, initial developments, and general overview of RTT. Chapter III presents the background and current operating parameters/limitations of MITLA/RF. Chapter IV outlines feasible implementation and integration strategies for exploiting the advantages of the technology. In closing, Chapter V contains the summary, conclusions, and recommendations. Definitions of abbreviations and key terms are presented in Appendices A and B, respectively. Appendices C and D provide examples of forms currently used to manage USMC ground equipment maintenance.

II. OVERVIEW OF MAINTENANCE MANAGEMENT AND AIT

A. GENERAL

With the recognition that the next generation of technology must provide the opportunity to close the battlefield information gap as outlined in " . . . From the Sea," and the increasing awareness of the potential benefits that Automated Identification Technology (AIT) and related RTT hold for the CSS community, the questions that most frequently occur concern the definition of the requirement and the actual means of getting these technologies into our systems. Today, hard work by well-trained and dedicated Marines assure that maintenance operations are not jeopardized by antiquated management methods, and that all mission objectives are achieved.

This has been accomplished, however, at a significant time and labor cost that can be directly attributed to current logistics practices, procedures, and equipment. This is of particular concern for future operations due to the combination of force "right-sizing," DoD budget reductions, and an evolving Marine Corps doctrine that places new demands on the ability to deploy and support tactical forces.

The Marine Corps has adopted a policy to develop a range of AIS that, when used together, greatly enhance the ability to plan for and deploy on multiple fronts with rapidly changing scenarios. However, the present systems are only indirectly associated with actual Marine Corps resources, and indirectly tied to the command and control planning functions that they affect. The existing CSS designs are supported by a labor intensive management system. Also a continual redigesting and reformatting of information content takes place as it flows upstream.

This chapter provides a framework for how USMC ground equipment maintenance is managed by first addressing levels of maintenance, maintenance production functions, and the Marine Corps' Integrated Maintenance Management System. Focus then shifts to equipment modification and preventive maintenance and the disadvantages of the associated (manual) records. The final sections introduce the diversity of AIT, their strengths and weaknesses, and the doctrinal constraints that must be met to successfully support emerging CSS operations.

B. MAINTENANCE MANAGEMENT

Organizational mobility, fire-power, and communications rests not only on dedication and training but also on the ability of the equipment to meet the demands. Maintenance is the logistics function of keeping equipment properly operating. This is essential to today's amphibious assault operations and will become even more important to MAGTFs as they employ concepts of over-the-horizon and maneuver warfare. Marine Corps maintenance echelons/production functions are subdivisions that permit the assignment of maintenance responsibility to various levels within units.

1. Levels of Maintenance

There are currently five echelons of maintenance within the three levels of the equipment maintenance support function. The three levels of maintenance can be thought of as a pyramidal hierarchy in that each higher level builds on the functions provided by previous levels. The first two echelons are organizational maintenance and are performed by the unit that owns the equipment. Echelons three and four, intermediate maintenance, are usually performed by mobile CSSEs and/or fixed specialized organizations and installations, although some organizational units can perform intermediate maintenance. These two echelons focus on repair by replacement and maintenance of those items critical to accomplishing the mission. The fifth echelon is the depot level maintenance for complete overhaul and/or upgrade of equipment, is found only at the MCLBs and cannot be deployed with amphibious forces. The fourth and fifth echelons are considered sustaining operations.

Organizational maintenance generally includes tasks performed by using organizations on their own equipment, first echelon maintenance by equipment operators/crews and second echelon maintenance by trained mechanics. Maintenance at this level includes cleaning, limited technical inspection, adjustments, lubricating, and parts replacement (minor assemblies, subassemblies, modules, and line replacement components such as filters, batteries, electronic boxes).

Intermediate maintenance is done by specially trained personnel in the owning unit or CSSE. This level usually involves calibrating, modifying equipment, repairing subassemblies, and exchanging major components (such as engines and transmissions). Intermediate maintenance also entails component and end item overhaul/rebuild, and emergency manufacturing of non-available parts at temporary sites.

Depot maintenance is performed in industrial-type facilities. This level supports the accomplishment of tasks above the capabilities available at the intermediate level. At this level major end items are overhauled and rebuilt using production line techniques, programs, and schedules. Depot level activities ensure continued system integrity, incorporate technical directives, manufacture or modify parts/parts kits, and execute equipment service life extension programs.

2. Maintenance Production Functions

Marine Corps maintenance production functions entail the following: 1. inspecting and classifying; 2. servicing and adjusting (PM); 3. testing and calibrating; 4. corrective maintenance (CM); 5. modifying; 6. rebuilding and overhauling; 7. reclaiming; 8. modernization; and 9. recovering and evacuating. Some functions generally are performed only by depots, while others generally are done by field units. The production functions are summarized in Figure 2.1.

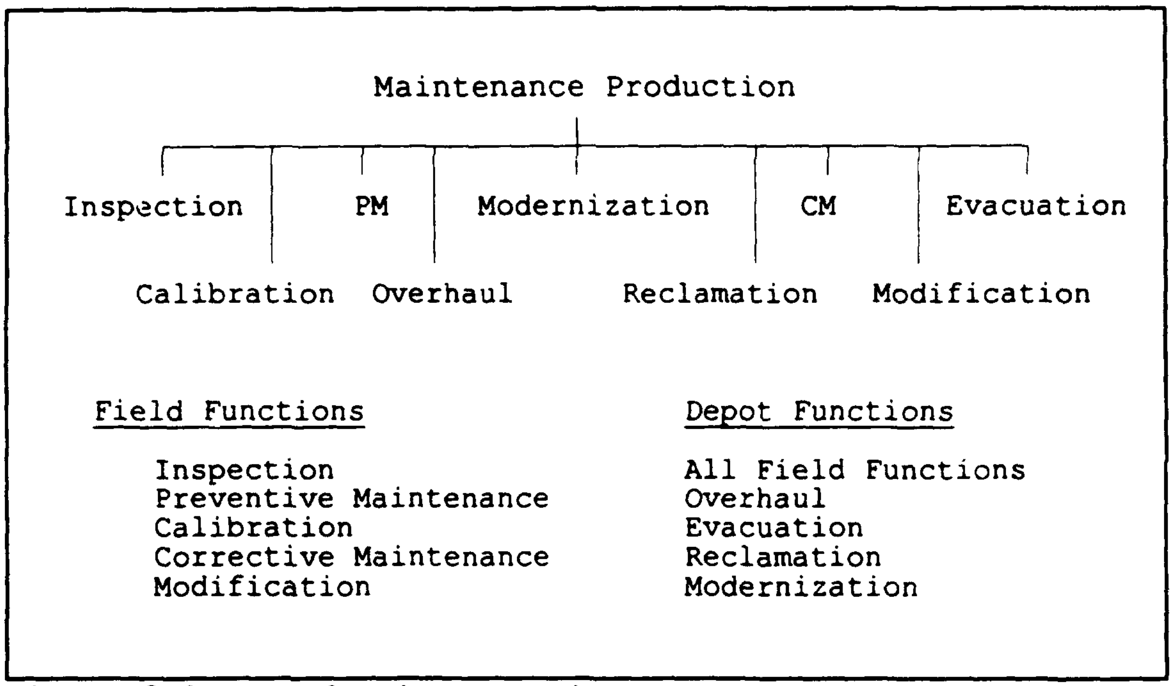

Figure 2.1 – Production Functions [Ref. 1: p. 3-3]

3. USMC Maintenance Program

Marine Corps Order P4790.1 establishes the Marine Corps Integrated Maintenance Management System (MIMMS) as the Corps' ground equipment maintenance program. MIMMS is an integrated management system encompassing all equipment commodity areas, based on standard policies and procedures.[2] These policies and procedures, with supporting information systems that recognize the distinct requirements of each maintenance echelon, are applicable at all levels of command.

Maintenance and maintenance management procedures/systems used in a garrison environment are designed so as not to differ significantly from those used when units deploy. Marine Corps maintenance management incorporates the following functional areas: [Ref. 1: p. 1-12]

- MIMMS AIS
- Supply Support
- Records and Reports
- Modification Control
- Publications Control
- Personnel and Training
- Equipment Availability
- Maintenance Administration
- Support and Test Equipment

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[2] Commodities are unit sections such as transportation, armory, communications, supply, medical, utilities, etc.

- Maintenance Related Programs
- Preventive and Corrective Maintenance

Maintenance information provides the basis for the management of the unit's equipment maintenance program. Maintenance information consists of reports, the MIMMS AIS database, and records. Maintenance reports contain data or information for use in determining policy, planning, controlling, evaluating operations and performance, and preparing other reports. They are generally summarized and may be transmitted on a recurring, occasional, or one-time basis. Finally, maintenance reports are prepared in narrative, tabular, graphic, questionnaire, tape, or other forms. Except for reports detailing equipment actively undergoing maintenance (MIMMS AIS) and equipment readiness (MARES), the multitude of required and "as requested" management reports are largely products of manual effort.[3]

Equipment records are those records that are maintained for a specific item of equipment. Marine Corps Technical Manual TM-4700-15/1 (Equipment Record Procedures) contains the detailed instructions concerning the purpose,

[3] MIMMS AIS, an amalgamation of mainframe/desktop computer programs, supports organizational and intermediate maintenance activities by providing standard/ad-hoc reports on active maintenance. The Marine Corps Automated Readiness Evaluation System (MARES) is a sister-system which reports unit equipment readiness as a function of equipment density and maintenance posture.

use, and completion of equipment and records. Depending upon a unit's equipment complexion and density, a unit may be required to maintain 20 or more records.

Resource records are maintained to document a unit's efforts. Examples include toolbox inventories, calibration schedules, vehicle dispatch records/logs, modification records, and PM schedules. Except for sporadic unit initiatives (i.e., not supported or standardized by higher headquarters), equipment/resource records are manual forms, folders, and rosters that require considerable preparation, maintenance, and management capital — demands that shift focus from actual "wrench-turning" operations to paperwork drills.

In the Marine Corps, unit/equipment integrity is often breached as a function of task organizing commands to meet specific operational requirements (i.e., equipment is temporarily transferred from owning units to MAGTF commands/borrowing units). Accordingly, owning units will provide "skeleton" equipment records for temporarily loaned equipment. Units borrowing equipment will maintain "skeleton" records including entries on maintenance actions performed. Upon return of equipment, borrowers return up-to-date equipment records and copies of all forms containing maintenance actions performed. Lenders then update all original records.

C. MODIFICATION AND PREVENTIVE MAINTENANCE

The smooth operation of a maintenance system depends on the understanding and completion of specified forms and records. These forms and records provide a means for establishing uniform procedures for control, operation, and maintenance. The forty-plus forms and records described in the TM-4700-15/1 are the minimum required for proper ground equipment operation/maintenance and are mandatory for use in the Marine Corps. Additionally, many of these equipment records must accompany equipment evacuated for maintenance, transferred, or temporarily loaned to another unit.

While many forms and records apply only to specific commodity areas, several are applicable to all commodity areas and required when equipment is used for contingency operations/field training, or when used as formal school training aids. Foremost among these multi-commodity forms/records are the Commodity Manager's Modification Control Record (NAVMC 11053/54) and the Preventive Maintenance Roster (NAVMC 10561) (see Appendices C and D). Although modification of equipment is a separate, distinct process, the determination of modification status of unit equipment can best be made as a part of the PM process. Because of the regular inspection of equipment during PM, combining this inspection with that for modifications can materially reduce both maintenance resource requirements and inconveniences to the unit's operation.

1. Modification Control Records

Equipment modification consists of those maintenance actions performed to change the design or assembly characteristics of equipment systems, end items, components, assemblies, subassemblies, or parts to improve equipment functionality, maintainability, reliability, and/or safety characteristics. Requirements for equipment modification, including the detailed step-by-step procedures for accomplishment, are published as Marine Corps Modification Instructions (MI) in response to technology advances, documented equipment shortcomings, planned product improvement packages, joint service operability requirements, and safety hazards. Modification Instructions identify specific types and items of equipment to be modified, modification kits, or parts and fabrication materials when kits are not prescribed, specific echelon of maintenance authorized to perform the modification, and maintenance resources, skills, and time necessary for their accomplishment.

Upon receipt of equipment, owning units conduct Limited Technical Inspections (LTI) to determine if all required MIs have been properly completed. When LTIs and required modifications have been completed, equipment records and NAVMC 11053/54s are updated according to TM-4700-15/1. NAVMC 11053/54s are prepared for each principal end item for which an MI has been issued. MIs targeting secondary reparables will be shown on the record for the associated principal end item. Upon receipt of newly published MIs, owning units of the equipment addressed will first determine specific applicability and will either requisition modification kits and complete the modification or forward equipment to a higher echelon of maintenance for modification if required. Upon completion of the modification(s), equipment records and NAVMC 11053/54s are again updated as stated above. The detailed, and often puzzling, NAVMC 11053/54 preparation instructions are printed on the back of the respective forms (refer to Appendix C). NAVMC 11053/54s are maintained as long as applicable equipment is retained on the unit's supply records. [Ref. 2: pp. 2.5.1 - 2.5.4]

2. Preventive Maintenance Rosters

Maintaining equipment in satisfactory operating condition is the goal of preventive maintenance. This is achieved by accomplishing the systematic inspection, detection, and correction of incipient failures either before they occur or before they develop into major defects. A systematic PM program consisting of inspecting, cleaning, servicing, lubricating, and adjusting is the key to equipment readiness in a unit. Effectively administered PM will help prevent early breakdown or failure of equipment, thus assisting in preventing costly, complex, and time-consuming repairs and in attaining the optimum use of maintenance resources.

NAVMC 10561 is used to schedule PM on equipment. However, units are authorized to schedule PM via locally developed automated programs (if the data elements duplicate those of the NAVMC 10561) until an automated PM scheduling capability is developed. Equipment chiefs (for commodities such as, engineering, motor transport, communications, etc.) are responsible for scheduling required services using the PM schedule set forth in the appropriate equipment technical manual (TM) and guidance of USMC Order (MCO) P4790.2 and TM-4700-15/1. [Ref. 2: p. 2.4.1]

All equipment and separate attachments are listed on NAVMC 10561s and scheduled for PM as required in the appropriate equipment TM. Attachments and/or major components are separate entries on the NAVMC 10561 regardless as to whether they are assigned to a particular principal end item or not. Complicating these requirements, maintenance chiefs must also stagger scheduled PM services to obtain a balanced maintenance load and maximum use of equipment. NAVMC 10561s on which all required maintenance services have been completed are retained in unit files for one year and may then be destroyed (except equipment requiring a separate and unique biennial service). [Ref. 2: p. 2.4.4]

3. Strategic Shortcomings

The aforementioned "paper drills" cannot effectively support unit requirements during the *dynamic* (read as: *chaotic*) environment found during short-fused preparations for training and contingency operations. Further, the above procedures deny activities beyond the owning unit access to the status of pending, ongoing, and completed equipment modification/PM actions. However, such statuses are routinely requested from equipment owners by divisional/force maintenance managers, USMC program managers, fleet supply activities, and various other USMC/DoD logistics commands. This information is typically sought to support critical decisions such as the following:

- Proposing/defining budget requirements
- Determining wholesale, intermediate, and retail inventory stockage requirements
- Performing Reliability Centered Maintenance (RCM)/Failure Modes Effects, and Criticality Analysis (FMECA)
- Planning missions (i.e., only particular equipment modifications may meet certain operational requirements)
- Addressing contracting/warranty issues (i.e., often modifications are executed under warranty programs, inadequate PM history may invalidate warranties)
- Adjusting/removing safety thresholds (i.e., modified equipment no longer poses a safety hazard to operators and may be eligible for return to "flight line" status)

To meet many demands for equipment modification, preventive maintenance, and general maintenance management information, equipment owners expend considerable time and effort identifying, gathering, collating, and preparing information for transmittal to requesting activities. Additionally, requesting activities consume even greater resources compiling, selecting, and analyzing the disjointed information to glean the facts required for specific decision making processes. In a nut shell, the opportunity costs associated with the current manual tracking methods are prohibitively excessive and can no longer be entertained during these periods of budget austerity and unfolding OMFTS concepts.

The emerging operational hypothesis of OMFTS, which requires seabasing, will further complicate locating, recording, and tracking modification/PM requirements for all classes of supply. As addressed, equipment maintenance management is largely a paper process that is man-hour intensive and receives little attention until equipment fails. New technologies are required to support maintenance management procedures during compressed time frames and from further distances in a dynamic and hostile environment. In addition, the OMFTS concept will require new data processing technologies for recording and transferring data quickly enough to support the logistics aspects of command and control.

D. AUTOMATIC IDENTIFICATION TECHNOLOGY

With the recognition of declining resources and the increasing awareness of the potential benefits that AIT and related technologies hold for the CSS community, the questions that most frequently occur concern the definition of the requirement and the actual means of getting these technologies into USMC systems. This section covers such diverse applications as barcoding, two-dimensional barcoding, softstrip, Optical Character Recognition (OCR page imaging), MITLA (smart cards, micro chips, laser cards, RF systems), speech systems recognition, and Artificial Intelligence (AI). Figure 2.2 depicts the evolutionary relationship within current AIT.

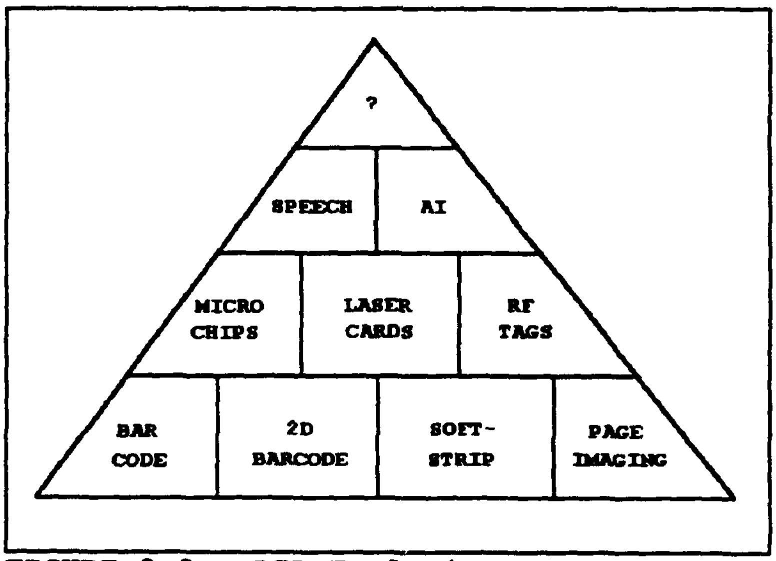

FIGURE 2.2 – AIT Evolution [Ref. 3: p. 5]

Though the technologies described in this section are varied, they share a common goal. All seek to provide a measure of valid, usable information with a minimum of effort by the information gather. In some cases, different technologies could be used to satisfy the same requirement. In that eventuality, the decision about which technology is preferable becomes a matter of cost, effectiveness, and ease of use. With other scenarios, the different technologies can work together to provide the logistics community with the opportunity to economically use the benefits of several.

Every commander/maintenance officer requires consistent, near real-time data about maintenance operations to foster sound and timely decisions. Whether the goal is to increase combat effectiveness, decrease costs, or improve "flight line" readiness, the first step is to accurately monitor the maintenance process. As discussed earlier, new technologies will be required to process unprecedented quantities of CSS data quickly to support the logistics aspects of emerging OMTFS concepts. New technologies mean old, inefficient, unresponsive data entry processes abandoned, and new risks ventured. The best way to risk-proof USMC systems is to understand available technologies first – how they operate and where they work most effectively. The following guide is designed to explain how these technologies can be used to save resources and enhance logistics operations.

1. Barcoding/Softstrip Systems

Barcodes are a series of thin or thick lines and spaces that signify numeric, alphabetic, and control characters. There are two "flavors" of barcoding symbology - one dimensional and two dimensional. One dimensional barcode is a generic term applied to many variable length structured data encoding symbologies. These codes have an inherent capability to encode relatively low information volumes in a given space. Two dimensional barcode is a generic term applied to many multi-row, continuous, variable length structured data encoding symbologies. These codes have an inherent capability to encode more information in a smaller space than the traditional barcode.

Barcoding's success lies in its relative simplicity. Reading devices detect either the existence or absence of a bar and transfer the information to a processor (handheld data collector or a PC) for decoding and processing. Although more advanced systems do not require direct contact, the reading devices (scanners) are normally distance limited and require line-of-sight to the barcode. The error rates for barcoding systems can be as small as one in 1.2 million characters read, certainly a significant improvement from error rates found in manual data entry. [Ref. 4: p. 1-2]

Barcodes are not appropriate in all environments. Barcode equipment operation failure is a function of bright sunlight, dirt, and grease buildup on barcodes and scanners. The strength of barcoding is in its use in counting, tracking, and identifying applications, typified by DoD's Logistics Applications of Automated Marking and Reading Symbols (LOGMARS) program.[4] They are most beneficial when used to gather several *small* pieces of data. If *large* descriptive pieces of information are to be gathered, other technologies are most useful.

Softstrip is a barcode-related technique of encoding information that appears as a structured pattern of black and white rectangles (on paper) vice bars and spaces. This inexpensive but slow optical technology allows text, graphics, or digitized sound to be encoded, applied to many different paper surfaces, scanned, processed, and (like traditional barcodes) retrieved when necessary.

2. Optical Character Recognition (OCR)

Unlike barcode systems which read a series of lines, OCR systems read stylized alphabetic characters and numbers so

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[4] One of the earliest DoD initiatives, LOGMARS was not intended as an Automated Data Processing (ADP) system, but rather as a technology which could provide a better interface between data and existing/planned ADP systems. The goal of LOGMARS was to improve productivity, timeliness, and accuracy; save costs; and provide basic formats applicable to future technologies. [Ref. 5: p. 2]

that people, also machines, can read the labels. OCR relies on a sensor to differentiate light-reflecting background and printed, nonreflecting data. OCR scanners are typically hand-held devices and are "wiped" across OCR labels/text in the fashion of a wand barcode scanner. In the banking industry, for example, OCR technology is used to sort volumes of negotiable paper (e.g. personal checks, bonds, certificates, etc.) by quickly interpreting the routing and accounting data imprinted on each document.

High quality printing and environmental control are essential with OCR equipment. Ink spots, dirt, or poorly printed labels/text can easily cause a misread or no read at all. OCR scanning techniques fall short because they are very sensitive to character orientation in respect to scanning equipment, and because of a requirement for sharp contrast between characters and background. Most OCR systems operate at a slower read rate than barcode systems. Although OCR accuracy is high, the "first read rate" is substantially lower than for barcoding and translates into greater dependence on operator performance. [Ref. 6: p. 79]

OCR is best suited where its human and machine readable capability is required. However, the technology is quickly evolving to the point where OCR may equal the accuracy and speed of barcoding. The cost of OCR systems is relatively inexpensive — about the same as barcode systems — though, like all AIT, OCR operating speed depends on sophistication and cost.

3. MITLA

As defined by DoD Instruction 4140.56, MITLA is "the generic term for the use of small, rugged portable memory/logic devices to receive, retain, and transmit logistics data in automated form [Ref. 7: p. 5]." MITLA devices are essentially intelligent labels providing a paperless method for attaching information to an item and for identification of items from a distance. They are commonly referred to as portable data carriers: smart cards, laser cards, magnetic stripe cards, radio frequency tags, and infrared devices (see Figure 2.3). Simply defined, MITLA is second generation LOGMARS using embedded microcircuits, radio frequency science, and other technologies to create and use "intelligent" labels.

It is important to realize that MITLA is an emerging and developing technology. Although the concept of microchip-based identification (which is the commercial terminology encompassing basically all MITLA) has been around since the 1950s, it has only been in the last decade that the technology has blossomed. In this regard, its development has mirrored many other high technology advances. As applications have

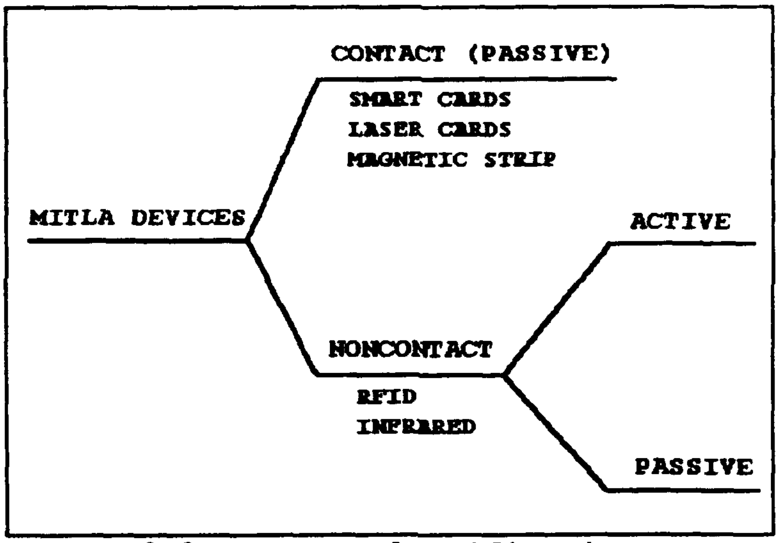

FIGURE 2.3 - MITLA Classifications

grown, competition has increased among manufacturers resulting in greater capacity, capability, utility, and availability, while also reducing costs and size of components. However, the market is far from mature and products representing today's technological cutting edge may be obsolete tomorrow. Furthermore, it would not be unreasonable to anticipate that today's microcircuit frontiers will also be pushed back in a relatively short amount of time.

MITLA systems are generally categorized as either contact or noncontact as depicted in Figure 2.3. The fundamental premise of microchip based identification systems is that a tag (transponder), containing data relative to the item it is marking, can transmit that data to a central database/AIS. Whether this data can be transmitted remotely without contact between the tag and the reader is the primary line of demarcation between available systems. [Ref. 7: p. 45]

Noncontact systems are further differentiated by their method of power generation – active or passive systems. Passive tags do not contain a power source, but rather extract their power from the radio frequency energy of a reading device. Conversely, active tags contain a power source, typically a lithium battery, enabling them to operate with "less" power from the reader. In either case, data is transmitted from the tag to the reader upon receipt of a query initiated by the reader. [Ref. 7: p. 46]

The following two subsections will briefly review the operational characteristics and provide a cross section of contact and noncontact MITLA devices. These are by no means comprehensive but are representative examples that can provide a springboard for creative thinking about potential applications.

a. *Contact Systems*

Contact systems require physical contact between decoders (read/write unit) and tags. Normally this is accomplished by full insertion of tags (or device) into readers. These technologies include smart cards, laser cards, and magnetic stripe cards that contain digital information stored physically or magnetically. All require direct contact between the tag and the reader, precluding permanent attachment of tags to material being marked. Likewise, all are subject to failure if the card is physically damaged. The ensuing discussion furnishes a brief description of the products that are most often included in the definition of MITLA contact systems.

(1) Smart Card. A smart card looks like an ordinary credit card. More accurately it is a miniature computer packaged inside a plastic, card-sized container. Like all computers the computer in a smart card has an operating system, a central processing unit (CPU), and internal memory. Unlike other computers, the smart card computer normally is inert. It has no power supply of its own. The smart card computer operates only when a special read/write device provides it with power and exchanges coded commands with its operating program.

The memory capacity of smart cards ranges from a several hundred bits to about four letter-sized pages of alphanumeric characters. Some cards contain memory that can only be written once, and others contain memory that can be rewritten over 100,000 times; however, there is no limit on the number of times memory can be read. The microprocessor is used to perform file management tasks, and, in some models, may also perform sophisticated routines for card-to-terminal authentication and card holder Personal Identification Number (PIN) verification. [Ref. 8: p. 60]

Smart cards are ideally suited to applications where a small amount of secure portable data is desirable. Smart cards are now being used in public telephones to replace coins, in health care for emergency patient information, for secure access control to buildings and computers, to scramble pay television signals, in mobile telephones, for electronic transfer of welfare benefits, in parking meters, for vending machines, as multiple application student identification cards, and in banking to replace magnetic stripe cards.

(2) Laser Cards/Optical Systems. Laser cards, also known as optical cards and optical memory cards, use a technology that is now beginning to emerge in the commercial marketplace. A laser card is a credit card-sized, flexible object much like a smart card. Optical systems are found in several forms including Compact Disk Read-Only-Memory (CD ROM), Write-Once-Read-Many (WORM), and writeable/erasable optical disks. The core technology behind these systems is based on the same laser devices found in home audio and video CD and laserdisc players. [Ref. 9: p. 27]

Optical recording focuses a beam of light (laser) through an optical lens on to the recording surface of the media. The recording surface for optical disk is a thin metallized coat approximately one millimeter (mm) thick sandwiched between two pieces of a rigid substrate [Ref. 9: p. 27]. As the light strikes a disk, information is digitally encoded on to the recording surface. How this is accomplished can vary depending on the type of optical disk, laser card, or recording device. Simplified, information is imprinted as a series of light and dark areas (the light areas are also called pits). The laser reads these light/dark reflections and interprets them as digital data.

The memory capacity of current technology laser cards is roughly equivalent to about 1,200 letter-sized pages of alphanumeric characters [Ref. 8: p. 60]. Potential laser card use envisions a wide range of applications, including medical records, technical documentation, and identification cards with digitized photographs and biometric data. Early CD-ROM systems were costly, with few features. However, today's CD-ROMs can store up to 650 megabytes (Mb) of data on a 4.7 inch disk (over 60,000 letter-sized pages). [Ref. 9: p. 27]

Like WORM optical technology, the recordable CD can only be written once, but uses a different method of recording the data. WORM recording places information on various sectors of the disk. For instance, information that requires security may be placed on another sector different from the primary sector the data is being written to. CD-ROM technology records information only in a linear format from the inside toward the outer edge. Since CD-ROM is intended for data distribution, information is permanently stamped on the disks.

As the name states, WORM technology offers the user the ability to write data just once. This media is intended for the long term storage of data and uses a number of methods to record the data. Currently WORM manufacturers offer two different formats, 5.25 inch and 12 inch media. The 5.25 inch medium has the storage capacity of over 320 Mb on a one-sided disk. The 12 inch medium can store data on both sides of the disk and has a capacity of up to three gigabyte, which is the equivalent of 60 American Heritage Dictionaries (12,000,000 definitions). One of the driving factors in selecting WORM storage devices can be the cost of the drives themselves. The average cost of a 5.25 inch WORM drive is upwards of $3,000, while the 12 inch drive can cost nearly $25,000. [Ref. 9: p. 31]

One of the major advantages of optical systems, such as laser cards/CD-ROMs, over tape systems is the virtually instant access to the desired data. Access times for an average CD-ROM, for instance, range from 200 milliseconds (ms) up to 800ms [Ref. 9: p. 27]. Because CD-ROM is designed strictly for data distribution it is also the cheapest of the optical systems to operate. However, the ability of optical systems to expand their storage capacities will be dependent on advances in laser technology.

Although laser cards, CD-ROM, and WORM offer unique capabilities with their market niche, rewriteable optical technology offers an alternative to those requiring short term storage of large amounts of data. Rewriteable optical devices have been on the market since 1990 and come in two primary forms, the 5.25 inch disk, which can store up to 500 Mb of data per side, and the 3.5 inch disk, which stores up to 128 Mb on each side [Ref. 9: p. 32]. Access time, like all optical disk formats, is virtually instantaneous. The growth potential for rewriteable will also depend on the advancements made in laser technology.

(3) Magnetic Stripe. Information is recorded on magnetic stripe much like that used in tape recorders. Like tape, the information on it can be changed. There is an industry-wide standard for magnetic stripe data encoding. Therefore, cards encoded on a machine made by one manufacturer can be read on any machine conforming to this standard.

Magnetic stripe data must be encoded on specially made cards by machines made for the purpose. That specialized equipment is required is an advantage in applications where security is a consideration, such as financial industries or personnel access control. The chief advantage of magnetic stripe identification is also its chief disadvantage: it is difficult to copy magnetic stripe identification tags. If the application calls for security in the transmission of confidential data, then magnetic stripes are a good option – virtually all credit cards and automatic teller cards use magnetic stripe technology.[Ref. 4. p. 1-14]

Because magnetic media is susceptible to strong electromagnetic fields, care must be taken to protect the cards. Also, the main drawbacks to this technology are reading range and speed. Information must be read via card reader or operators must use a hand held reader; thus eliminating most high speed sortation applications. Magnetic stripes can, however, be read through dirt or grease, which image based technologies like barcodes cannot do. The multiple track and coding of magnetic stripes makes them resistant to tearing and crumpling.

b. *Noncontact Systems*

Noncontact systems enable the encoded information on tags or cards to be read from a distance using infrared or radio frequency energy. By far the most common method employs radio transmitters and receivers in the radio frequency mode.

(1) Infrared. Infrared technology uses that portion of the electromagnetic spectrum adjacent to the long wavelength, or red end of the visible light range. Invisible to the eye, it can be detected as a sensation of warmth to the skin. Heated objects were the primary sources of infrared (radiation) before the discovery of lasers; the latter became available in the early 1970s for many specific sharp frequencies (narrow lines). Most of the radiation emitted by a moderately heated surface is infrared light. Infrared technology, as found in MITLA laser-type scanning devices, generally uses a form of tag (molecular) excitation that produces copious infrared radiation but in a discrete spectrum of lines or bands. [Ref. 10: p. 455]

These lines or bands of infrared light can be programmed to represent specific alphanumeric characters and allow for subsequent information gathering over moderate distances. Similarly, infrared technology can also be used to read some types of "standard" barcoding. Although lasers and infrared technology are highly promising noncontact MITLA sources, their line-of-sight restrictions, safety considerations, and general complexity limit their practical applications at this time.

(2) Radio Frequency. Radio Frequency Identification (RFID) refers to systems that read data from RF tags that are present in an RF field projected from RF reading equipment. Data may be contained in one or more bits for providing identification and other information about the object to which the tag is attached. [Ref. 4: p. 1-27]

RF technology employs a small integrated circuit with an electronic memory, an antenna system, and a reader. The reader functions similarly to the decoder in a barcoding installation, and the antenna like a scanner; however, this is where the similarity ends (see Figure 2.4). A small RF transponder – or electronic identification tag – stores data that is read by an antenna unit attached to a reader. The identification tag can contain a fixed identifier or it may be programmable, depending upon the type of system in use. In passive RF schemes, tags have no internal power source; on the other hand, in active RF, tags transmit stored data back to the reader using their own power source (battery). The advantage of active devices is the greater effective range over which tags can be interrogated/read. [Ref. 11: p. 76]

Because RF noncontact systems use radio frequencies to operate, MITLA devices operating on the RF principle are susceptible to electrical interference (as in any radio system). Similarly, RF systems can interfere with other electronic devices. To reduce this risk of interference, MITLA producers use low power and signal encoding schemes. Tag reading, however, can be disrupted or degraded by metal obstructions that prevent radio waves from reaching the tags.

RFID systems and RF tags offer the following general benefits that collectively, provide discernable advantage over other MITLA devices (see Figure 2.4):

- Store/process large amounts of data.
- Provide read/write capability, allowing information update regarding item status, content, and physical condition.
- Maintain read/write capability even when items they are attached to are moving and not in "direct" physical contact with interrogators.
- Operate over distances far greater than other systems (RFID reading range currently extends to approximately 150 feet from interrogators).
- Allow placement under, in, or coverage by containers/products to which attached (physically inaccessible areas) because they are not limited by "line of sight" restrictions. Furthermore, darkness, dirt, or other non-metallic opaque substances will not affect tag readability.
- Report directly to RF interrogators which then transmit data to a CPU without human intervention.

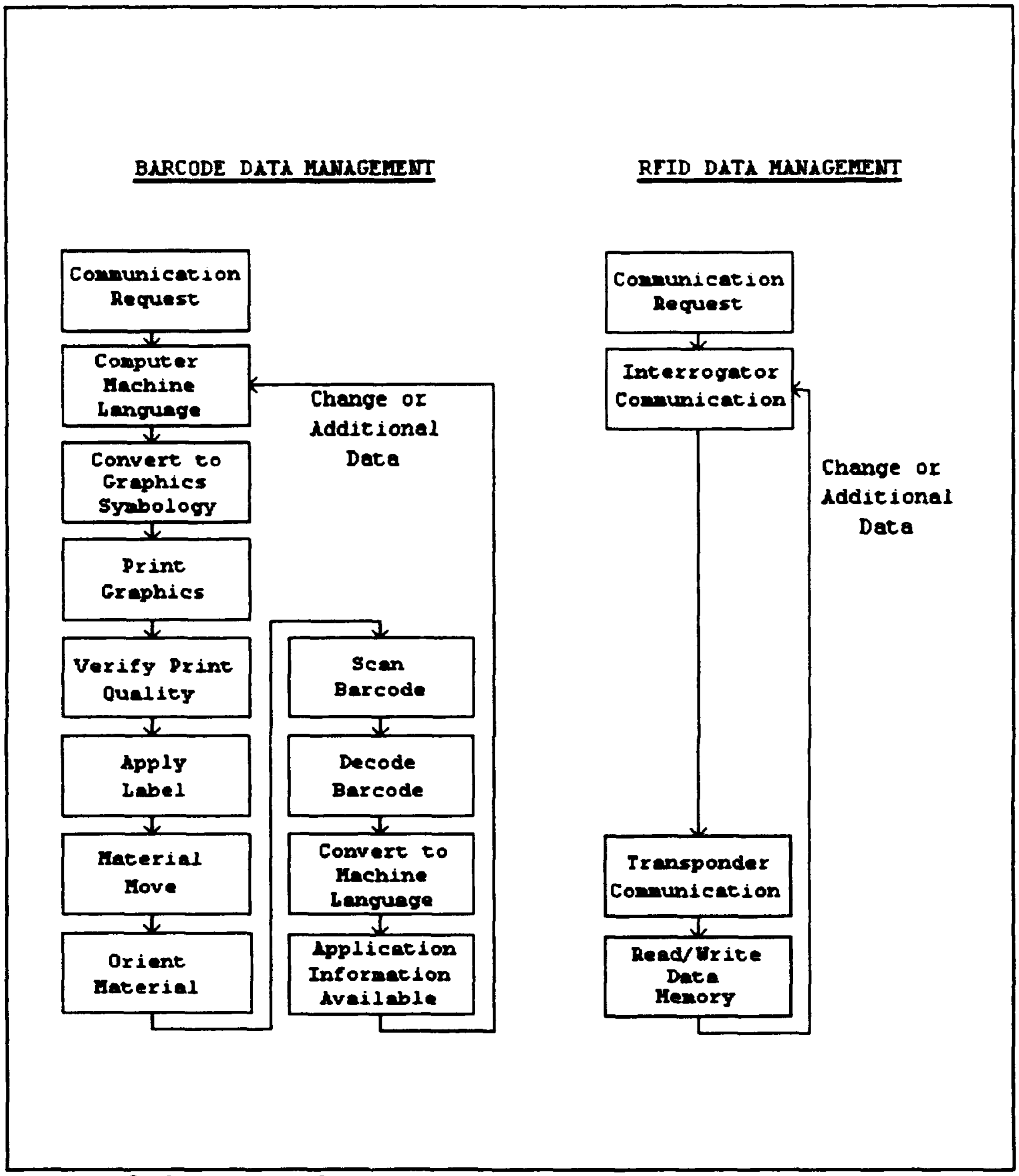

FIGURE 2.4 – Barcode vs RFID Management [Ref. 12: p. 2-6]

4. Speech Recognition

Speech recognition is distinct from speech synthesis and voice store-and-forward systems in that it actually "hears" words and either (1) performs predesignated tasks based on those words, or (2) stores the spoken information for later use. Existing technology generally requires single, discrete word entry though some prototype systems are now available that recognize limited continuous (natural) speech. Systems that require the user to "train" the unit to his/her voice — speaker dependent — or to recognize spoken words from a large number of users — speaker independent — are available.

Both systems use pattern matching processes to determine the identity of a word, but in a speaker dependent system the matching pattern consists only of the user's voice characteristics, while a speaker independent system uses a database of "average" patterns drawn from a large sample of voices. Not surprisingly, the speaker dependent system is more accurate while speaker independent devices provide greater flexibility. [Ref. 4: p. 1-4]

A typical speech recognition system uses a handset and microphone to enter words into the computer-based system for processing. Wireless microphone units are particularly useful in environments with dust, dirt, temperature extremes, and other hazards. Speech synthesis devices are often used in conjunction with the speech recognition unit to provide feedback and direction to the user. These systems provide automation capabilities in environments where users are not computer literate or where keyboards or similar input devices are not practical. Such systems could be designed to interface with RF tags or other similar recording devices; however, their contribution to maintenance management and CSS operations is constrained by today's "stand alone" speech recognition technology. [Ref. 4: p. 1-5]

5. Artificial Intelligence

Artificial Intelligence (AI) is the use of computers to model the behavioral aspects of human reasoning and learning. In problem solving, one must proceed from a beginning (the initial state) to the end (the goal state) via a limited number of steps. Research in AI is concentrated in some half-dozen areas. Examples include game theory, pattern recognition, natural language processing, and cybernetics.

In game theory the computer must choose among a number of possible "next" moves to select the one that optimizes its probability of winning; this type of choice is analogous to that of a chess player selecting the next move in response to an opponent's move. In pattern recognition, shapes, forms, or configurations of data must be identified and isolated from a larger group; the process here is similar to that used by a doctor in classifying medical problems on the basis of symptoms. Natural language processing is an analysis of current or colloquial language usage without the sometimes misleading effect of formal grammars. Cybernetics is the analysis of the communication and control processes of biological organisms and their relationship to mechanical and electrical systems; this study has led to the development of "thinking" robots. In this context, machine learning occurs when a computer improves its performance of a task on the basis of its programmed application of AI principles to its past performance of that task.

The first essential difference between existing computers and the human brain lies in the way their memories are organized. In either case, the main problem lies in retrieving information once it has been stored. The method computers use is called addressing; it is possible to find a certain piece of information if the address is known. The human memory works in a very different way, using association of data. The retrieval is done according to the content of the information, not according to an external address artificially added to the useful content. That difference is qualitative as well as quantitative. Man-made memory devices are now constructed using associative principles, and there is a great potential in this field with such new technologies as holography and optical storage of data.

The second main difference between computers and the human brain resides in the manner of dealing with the information. A computer processes rigorously precise data. Man accepts *fuzzy* data and carries out operations that are not strictly rigorous. Also, computers perform only very simple elementary operations, producing complex results by performing a vast number of such simple operations at a very high speed. In contrast, the human brain performs at low speed but in parallel rather than in sequence, producing several simultaneous results that can be compared. In a computer, memory and treatment are distinct; in man, they are mixed. [Ref. 13: p. 1034]

Related to AI, machine vision employs the same basic idea as OCR in that it involves scanning an identifying object and interpreting what it sees. Currently, machine vision is used mostly in Computer Integrated Manufacturing (CIM) systems to verify procedures or to measure assembly variations and forward information to enable downstream operations to adjust. Advances in AI and development of better pattern recognition capabilities will make concepts such as machine vision more practical options in sortation, inspection, and quality control applications. [Ref. 14: p. A22]

The combination of new man-made components with emerging ideas could result in entirely new AI technology in the 21st century. Advancements in AI will certainly make the challenge of command and control much easier to meet, however, much of this technology is still in its infancy. At this stage, AI concepts are high-risk, high-cost, and not within DoD's "reach." The remarkable developments being made in AI open the doors to many new military possibilities, nonetheless, DoD's actions must be balanced against a multiplicity of current obstacles to ensure a viable force is in place to capatilize on future AI developments. MITLA, in an open systems concept, could provide the bridge to cross from manual, repetitive actions to the mystical level called the "state-of-the-art."

E. TECHNOLOGY CONSTRAINTS

Logistics support operations are influenced and constrained by each step in the logistics process. Constraints range from procurement through operation, prepositioning, embarkation/debarkation, and maintenance support operations. The ability to successfully complete each step of the logistics process directly impacts the commander's ability to track the battle, anticipate requirements, locate equipment, manage critical resources, and meet CSS requirements to help sustain the force. AIT can be used at all echelons throughout the Marine Corps, from the sustaining base or seabase, which could be depots or installations, through the intermediate maintenance activities, to the operational units on a 24-hour-per-day basis.

This concept may be limited if the principal technology and functional barriers to achieve an effective recording, and tracking system based upon global and total asset visibility, in-transit visibility, and improved maintenance management are not addressed by DoD. The technology must be based on interdependency, boundary determination, sufficiency, transparency, interoperability, and functional focus.

The interdependency of CSS and AIT is most affected at the logistical end. Actions taken at the logistic level to enhance sustainability of operating forces must be considerate of Marine Corps CSS practices and capabilities. Maintenance requirements and services that are planned for, developed, or procured by the supporting element must meet the needs of the end-user, "warfighting," whenever possible.

The heart of logistics is requirement determination, and with the new logistics automated information services it will be more accurate, faster, and more stable. Boundary determination is the result of requirement assessment and is critical to the operational and tactical levels of war. Commanders must be apprised of the boundaries in which they conduct warfighting. While the classic CSS estimation process is effective in a course of action development, the operational trend is toward technological developments in command and control that are attempting to provide the commander with a near real-time battlefield picture.

Sufficiency relates primarily to operational readiness (quantities of supplies, maintenance posture, etc.) and CSS capability inherent with forward deployed MAGTFs. Sustainment is a key factors that makes our Naval forces a viable deployment (strategic) and employment (tactical) option.

While interdependence links logistics and CSS, transparency relates to the capability to perform the mission in today's rapidly changing world. The performance of logistic and CSS tasks must be transparent relative to their being carried out in peacetime or during a contingency. This transparency must be applicable to both the provider and receiver of CSS. The emerging concepts of RTT and advanced information systems will provide this transparency.

Interoperability is both the capability of Marine and Naval forces to share supplies/services and for expeditionary forces to use joint and combined CSS resources. Interoperability of Automated Information Systems (AIS) is critical and the innovative steps taken with logistics systems and subsystems need to continue. Interoperability also pertains to host nation support; the ability to access and then use in-country resources to the maximum extent possible is an important factor of MAGTF sustainment. The application of AIT through RTT systems and advanced information and communication systems will afford this interoperability.

Finally, the last tenet of the emerging warfighting concept is functional focus, which will facilitate change. Without the stimulus for change, systems or organizations grow obsolete and cannot meet the new concepts of the future. The six CSS functions of maintenance, supply, transportation, medical, engineering, and services must be analyzed in relation to the emerging concepts and technological developments (AIT, RTT, MITLA, etc.).

III. MITLA RADIO FREQUENCY IDENTIFICATION

A. GENERAL

RFID uses the concept of radio wave transmission and reception to pass information about objects that need to be identified or tracked. These objects can be such diverse items as vehicles, aircraft, pallets, or containers. The information is stored on tags with media storage capability similar to computer floppy diskettes. Antennas, scanners, or interrogators can read information contained on tags attached to items and pass it back to central information systems. Under certain conditions, it will also be desirable to write to tags from interrogators to update information concerning tagged items. It is this remote "stand-off" read/write capability that sets the RF tag apart from other AIT, such as barcoding.

RFID technology can guide a robot through a factory maze to its proper tools; it can verify personnel security clearances – even changing security information as individuals pass through check points; it can track specific fish in migration studies; it can track containers in an environment filled with harsh chemicals, sprays, grease, and shifting temperatures; RFID can be used to store, process, and track life-to-date maintenance data on equipment items. The underlying theme in these and similar applications is to eliminate manual effort, streamline job processes, shorten logistic response times, improve material accountability, increase mean-time-between-failures (MTBF) rate/equipment life expecantancy, and support decision making.

B. PROMISING TECHNOLOGIES

The Department of Defense has been conducting a program to reduce the generation of and reliance on manually-prepared documentation. To reach this objective, the emphasis has been placed on exploiting advances in many different forms of technology. Several initiatives show promise of significantly reducing the existing paperwork burden experienced in logistics operations and providing the requisite tools necessary to simplify command, control, communications, computers, intelligence, and interoperability (C^4I^2) in OMFTS scenarios. When emplaced, this modernization and automation of logistics operations will result in better support to operating forces. Microchip tags (both contact/near contact and radio frequency) are part of one such technology advancement. This thesis explores the use of microcircuit technology for the storage of preventive maintenance, equipment modification, and repair data.

Many technologies have emerged over the last decade that show promise for remedying the situation caused by the loss, inaccessibility, destruction, and compartmentalization of important logistics/maintenance data. The common thread among these technologies is that they offer an alternative to reliance on hard-copy documentation and manual record keeping. Recent advances in data-recording technology offer the opportunity to examine ways to improve existing systems that are error-prone and require repetitive data entry. One of these, barcoding, is an inexpensive method for identifying items reliably and can be dependably employed when data about items can be maintained satisfactorily in a central database.

Microcircuit technology is another advance that has come to the forefront in recent years for relieving the burden of manual record keeping. It offers the advantage of recording and storing data reliably and eliminates the need to enter the same data again. The advent of data communication terminals and microchip tags that employ radio carrier waves for the transmission of data is just beginning to be recognized as a very promising technology. RF tags are becoming more capable and usable in numerous data storage applications. As with other recent advances in data handling, RF microchip technology is now undergoing investigation as a means to improve many labor intensive logistics functions. In this regard, Figure 3.1 depicts one view of the correlation between requirements and emerging RF technology.

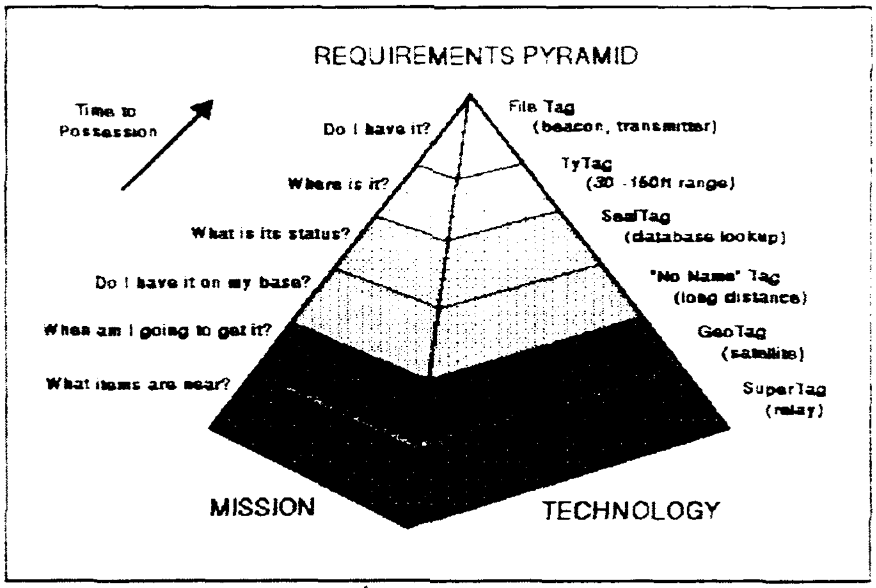

FIGURE 3.1 – MITLA/RF Pyramid [Ref. 15: p. 19]

Garrison and deployment experience in handling and controlling equipment maintenance data accompanying important components and PEIs has clearly pointed out the requirement for greater improvements in this area (refer to the MITLA survey discussed in Chapter IV). The availability of complete and accurate records of maintenance/modification/ repair is essential. The loss or unreliability of records that accompany an item throughout its service life may cause premature equipment disposal, inappropriate equipment assignment, or adversely affect unit readiness and/or safety. One solution to the loss of finite maintenance data was researched in the David Taylor Research Center's "Asset Visibility" project. Microchip tags used to store repair data were investigated and shown to be reliable devices for the storage/ retrieval of this critical logistics data. [Ref. 16: p. 3]

C. DESCRIPTION OF RFID TECHNOLOGY

RF technology involves the use of radio transmitters and receivers to transmit and receive data in near real-time and without connection, scanning, or human intervention. There are two basic types of RF technology: passive (modulated backscatter) and active (two-way transponder).

- Passive tags contain no internal power source. They are externally powered and typically derive their power from the carrier signal radiated from a scanner; however, externally generated power may prove unsuitable for use around some hazardous/explosive items. With backscatter technology, the tag is a "dumb" terminal that acts as a mirror to the radio waves emitted by a scanner. When a tag is activated, the radio waves are reflected back to the scanner. When the tag is not activated, the waves are not reflected.

- Active tags use batteries as a partial or complete source of power, but have a limited useful life and must be replaced periodically; tags can also include built-in diagnostics to inform the system when batteries are low. They are further differentiated by separating them into those with replaceable batteries and those that have batteries inside a sealed unit. Currently the typical tag battery life is three years, depending on the amount of use, and rechargeable battery technology limits the size of the tag. [Ref. 17: p. 6]

Transponder technology provides true two-way communication between scanners and tags. A transponder is a complete radio receiver and transmitter in one. The tag accepts the signal, processes the data, and emits a return signal to the scanner. The tag also is a more efficient communicator, is not orientation sensitive, and can initiate communication when it has something to report.

Remote tag reading range currently extends approximately 150 feet from interrogators (fixed or remote). The amount of data that is carried by tags can be tailored to individual requirements. Current technology allows up to 8,000 characters of data to be available for reading/writing operations. However, it is likely that in the future tag capabilities of 64,000 and 128,000 characters will be available, and as technology matures, even greater capabilities are anticipated. It is foreseen that the data carrying portion of tags can be partitioned into read/write sections (similar to standard computer floppy disks). Potential also exists to divide tags into sections for use by various commodity areas (i.e., transportation, maintenance, supply, embarkation, etc.) with access to common data on a read only basis. It may also be possible to configure tags with internet addresses and internet accessibility, thus eliminating cumbersome database structures for messaging purposes. [Ref. 17: pp. 7]

Automatic Equipment Identification (AEI) uses RF transmissions to collect and transfer identification data about a specific equipment item. An AEI system consists of an AEI tag (one per item) and a tag scanning device (one per read location). As the equipment and its tag are brought within scanner range, the scanner's RF transmissions interrogate the tag to read/write encoded data. If required, this data is then relayed to the system's host computer for storage and processing. The goal of AEI is to reduce/eliminate labor intensive manual data collection processes, LOGMARS scanning, and courier disk procedures currently in use.

Although AEI offers many measurable advantages over other marking and tracking technologies, there are also certain challenges that must be addressed. At a minimum, several issues must be evaluated: cost, tag reliability, data integrity, environmental limits, standardization, network compatibility, and operational doctrine.

♦ Equipment costs are typically direct functions of RFID models, memory capacities, and reading ranges. The models used are broken into low and high operating frequency. With low frequency, tag values range from a low of $7 up to $210. Interrogator values are also quite varied, with a range from $500 to $4,500. The differences are largely in the packaging. With high frequency equipment, the greatest number of tags i in the $35 range with a high of $150. Scanner system costs range from $1,200 to $5,600 because of the high cost of the reader points. The high frequency systems provide significantly different performance characteristics than low frequency and that justifies the increased scanner costs. [Ref. 4: p. 2-6]

♦ The questions of tagging reliability and data integrity are often overlooked in the design of an AEI installation. The certainty that each memory module has been written to or read from correctly is the central issue. Data integrity is affected by factors such as orientation, range, separation of modules, environment, and error management. Error checking is accomplished in different ways by various manufacturers, however, the best AEI will not work if a tag is attached to an incorrect PEI. [Ref. 4: p. 3-28]

♦ Any RF tagging system is subject to radio interference. High frequency signal energy is susceptible to absorption by liquids and grease, thus introducing signal attenuation and distortion in environments such as maintenance facilities and shipboard spaces. Multi-pathing ("crosstalk") due to reflection of emitted signals off surrounding metal is another point to evaluate and is usually a limitation found in very high frequency transmissions. [Ref. 4: p. 3-23]

♦ RF tag manufacturers must press for industry-wide standards if they are to achieve the widespread acceptance of barcodes or magnetic stripes. Currently, individual countries' regulations assigning electromagnetic spectrum bands are different from other countries and significantly impede worldwide standardization. In fact, today these dissimilar policies encourage non-standardization. [Ref. 4: p. 6-9]

♦ Expansion must also be considered - all identification techniques and work stations required now and in the future should function together in a seamless C^4I^2/LOGAIS network. One disadvantage, or better stated, challenge, to working with AEI and portable database systems is that concepts of maintenance management must be revisited and new processes learned. This, however, will give the Marine Corps the opportunity to improve its maintenance facility designs, maintenance production flow, and data process strategy.

D. FLEET OPERATIONAL NEED STATEMENT (FONS)

Emerging Marine Corps doctrine emphasizing high maneuverability and fire power with minimal lines of communication requires timely logistics support of precisely what the battlefield commander requires. This demands a logistics system that maintains accurate, near real-time data on commodity identification, "flight line" status, quantity, and location, capable of quickly responding to demands from forward combat elements. New technologies are required to automatically locate and track logistic items, container inventories, and equipment maintenance requirements; further, technologies are also needed for data processing and information management to record and transfer this data in support of the logistics aspects of C^4I^2. To meet these goals the Marine Corps has identified minimum desired characteristics, system architec-ture, and support requirements as detailed in the following subsections.

1. Desired Characteristics

The primary goal of the Marine Corps' Battlefield Automated Identification Technology (BAIT) R&D initiative, of which MITLA is a central component, is to provide near real-time updates on supply inventory [Ref. 18: p. 4]. Although not specifically addressed in the BAIT R&D initiative, the MITLA technology chosen for inventory management should provide a suitable platform to support key maintenance management functions. Specific characteristics as delineated in the FONS include:

- ♦ Tags and their supporting systems must be inexpensive, simple, and portable. Operation and application must be completely intuitive with transparent operation, requiring little or no training. The goal is no additional labor, and preferably a reduction in required work force. Manual data entry should be only made once, and possibly not at all.

- ♦ Tags must be small, lightweight, and compatible with items, including explosive ordnance and hazardous materials. They must be reliable, have long battery life, be very rugged, and operate in adverse military environments.

- ♦ Transmission must be secure, non-interceptible, and not susceptible to either intentional or non-intentional interference. Tags must not generate a "signature effect" that can be used for adversarial targetting and homing.

- ♦ Transmission should operate over distances found in warehousing yards and have Low Earth Orbit (LEO) satellite communications capability for greater distances.

- ♦ Tags and interrogators should talk to other tags and interrogators within their area to form networks and relay information, or to read much less expensive tags attached to individual items for automatic inventory of internal nested items. Operation must be unlicensed.[5]

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[5] The Federal Communications Commission (FCC) regulates commercial radio communications, including licensed and unlicensed communications, in the United States. Licensed communications require the granting of a specific channel for

♦ Tags must have sensing capability including geolocation, time, temperature, humidity, weight, and break seal.

♦ Tags must have adequate data storage to support supply, embarkation, ammunition, and equipment technical data and to contain complete container manifests. Tags must have internal database capabilities to minimize tag communication intensity and to speed data searches.

♦ No new information systems/platforms must be required. Only the tags, interrogators, stands, cables, and portable computers that directly support the MITLA technology will be considered. New software must be supportable by current/planned DoD open systems architectures and communication/networking protocols.

♦ Secondary goals include:

- ▲ Locate items in storage.
- ▲ Locate items issued and in use.
- ▲ Provide near real-time update on supply.
- ▲ Provide In-Transit Visibility (ITV).
- ▲ Provide visibility of items during maintenance. [Ref. 18: pp. 4-5]

2. System Architecture Requirements

Additional system operating parameters include:

♦ International operability.

♦ Open/public domain protocols.

♦ Unique addressable identifier.

♦ Non-site license (international).

♦ Optional data security/data encryption.

♦ Data capacity adjustable to requirements.

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a specific user, at a specific site, for a specific purpose. The advantage of licensed communications is increased range. The disadvantage of licensed communications is regulatory control for each transmitter, user, and site. [Ref. 19: p. 1]

♦ Provide source data automation capability.

♦ Downward compatible (compatible with all transponders with respect to interrogators).

♦ Unique transponder parameters to be considered are:

- ▲ Read/writeable.
- ▲ Automatic recognition.
- ▲ Tag life span ≥ ten years.
- ▲ Various attachment methods.
- ▲ Battery durability ≥ five years.
- ▲ Non-orientation sensitivity (omnidirectional).
- ▲ Data transfer rate of ≥ 9600 baud and an upload/download time not to exceed one minute.

♦ Unique interrogator parameters to be considered are:

- ▲ Discrimination.
- ▲ Omni-directional.
- ▲ Multiple transponder query.
- ▲ Individual transponder query.
- ▲ Memory buffer capacity ≥ four Mb.
- ▲ Variable attenuation (directional).
- ▲ Transportation industry compatible.
- ▲ Operable with 12/24 volts (fixed interrogator).
- ▲ US military frequency bandwidth (225MHz-400MHz).
- ▲ Solar operable/battery backup (hand-held remote interrogator).
- ▲ "Locate ability" (Global Positioning System [GPS] or directional finding capability).
- ▲ Personal Computer (PC) compatible Microsoft Disk Operating System (MS DOS)/DoD system integration. [Ref. 17: p. 7]

3. Support Requirements

Tags may be battery operated, requiring adequate supplies of replacement batteries. Inexpensive tags must be expendable, and new tags must be available to mark new items/cartons. More costly tags must be reusable, but inexpensive enough to be disposable after failure. Information management will be hosted on either portable computers and/or existing or planned C^4I^2 systems and equipment. Training should be offered to individuals in C^4I^2 and/or in the logistics community on how to prepare and use tags and resulting software systems. [Ref. 18: p. 5]

E. USMC INITIATIVES

A USMC MITLA/RF system is under development to support theater reception capability for CSS buildup ashore; enhance MAGTF CSS effectiveness; and improve asset visibility, tracking, and documentation during retrograde operations. Capabilities successfully demonstrated in the foregoing will form the basis for applying MITLA/RF technology to MAGTF predeployment and deployment activities. Although primarily intended to support a MAGTF commander's asset location identification and tracking requirements, use of the USMC MITLA/RF system prototype will support improved logistics functions in non-MAGTF venues such as bases and stations.

The USMC MITLA/RF system prototype encompasses the hardware, software, policy, and procedures required to apply MITLA/RF technology, and, through interface with USMC LOGAIS and non-USMC automated logistics systems, to integrate material movement and management data. LOGMARS technology will provide source data automation by permitting barcoded data to be scanned and written directly into MITLA/RF hardware. This linking of applied MITLA technology and integrated materials movement and management data will give Marine Corps logisticians improved asset location identification, tracking, and control. [Ref. 12: pp. 1-2]

The primary objective of this process enhancement is to significantly improve force preparedness in theater. The MAGTF commander will immediately know equipment availability and location. The result will be more effective and efficient CSS, and increased combat readiness. The next logical evolution in the system's development is an expansion to include equipment maintenance management.

1. SAVI R&D Effort

The Marine Corps is participating with the Navy for MITLA/RF applications in a series of joint research and development efforts. This is being accomplished as a Small Business Innovative Research (SBIR) initiative that evaluates available technology for MITLA applications. This effort reviewed available inventory tracking RF technology for selected prototype testing at five sites, three Navy and two Marine Corps (Blount Island Command [BIC] and a North Atlantic Treaty Organization [NATO] prepositioned site). The product approved through the SBIR initiative was the SAVI tag.[6] The technology and applications related to the tag are available for exclusive Marine Corps employment. The prototype efforts underway at USMC sites include:

♦ BIC Prototype. Conceptual design centers on implementation of SAVI technology to support Maritime Prepositioning Force (MPF) operations at BIC. This prototype concentrates on container management and major end item tracking during the MPF offload/maintenance cycle.

♦ NATO Prepositioning Prototype. An additional prototype is underway for selected aspects of inventory management and inventory processing relative to prepositioning of NATO requirements. This is anticipated to be a static environment capitalizing on SAVI applications concerning shelf life and inventory security. [Ref. 21: p. 4]

2. Description of SAVI Tag Technology

The SAVI Technology TyTag is an RF asset management device that uses a radio transmitter, a receiver, a micro-computer (console), and memory to automatically track the location of an object to which attached. The TyTag system can

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[6] As announced in the Commerce Business Daily, Savi Technogoly, Inc., was awarded a sole source contract for procurement of radio frequency transponders, fixed interrogators, and hand-held interrogators (including maintenance). The equipment must be capable of operating on ships, airplanes, and land vehicles and in artic, desert, and tropical climates, including areas with high levels of electromagnetic interference. [Ref. 20: p. 32]

track the position and movement of containers, vehicles, major end items, and inventory from a remote position, regardless of the number of tags in the area. Using a microminiature radio transmitter it can locate an item in a warehouse, marshalling yard, container port, or aboard ship. Another variant uses a unique radio communication system to periodically monitor the movement of tagged items within a facility. As tagged items pass check points, a microprocessor begins an encoded exchange with the TyTag (via RF) and the system then accurately identifies tagged items and their locations, all without human involvement. [Ref. 21: Encl. 1: p. 1]

TyTag systems consist of four components: the TyTag, an interrogator, a console, and a sniffer (see Appendices E and F). The TyTag is affixed to an asset to be tracked and contains a small transmitter/receiver. Interrogators can be either permanently installed or used as portable antenna sets that can be mounted on ceilings, or on masts/tripods (e.g., telephone pole) in marshalling areas. The purpose of an interrogator is to communicate/transfer data between individual tags (via RF) and consoles. The console is a microcomputer that manages the communications with the interrogator and serves as a point of entry into the inventory tracking/ management system. It has a graphical interface for easy access to the database dependent upon the type and application of the SAVI tags employed. Properly configured, this microcomputer software could support MAGTF LOGAIS for container manifesting, inventory management of container contents, and general receipts, issue, and storage functions. The last component, the sniffer, is a hand-held portable interrogator used to locate assets and read/write data to TyTags. [Ref. 21: Encl. 1: p. 1]

The following sections discuss the primary features of the TyTag and the family of SAVI TyTag-based products [Ref. 21: Encl. 1: pp. 2-3]:

♦ Unlicensed Use. SAVI's products do not require a site license for use. They operate at a frequency within the FCC's unlicensed communication band.

♦ Read Range. Tags have a read range from fixed interrogators of 30 to approximately 150 feet. The exact range will depend on the system development requirements.

♦ Data Capacity. Various tag models have memory capacities ranging from 1024 bits (120 characters) to 64,000 bits (18,000 characters) with models under consideration with even greater capacity.

♦ International Use. SAVI's tags can be developed for international use. The operational concept enables tags to operate unlicensed worldwide. Fixed and portable interrogators can be set to operate on a specific country's unlicensed frequency band and tag receiver's can then scan through unlicensed ranges until the appropriate range is found.

♦ Active Tag/Transmitting. Tags are based on two-way transponder communication. This permits direct, low power communication between the tag and the interrogation units. SAVI's system software provides the capability to read multiple tags within a single area and have them be reliably identified. Line-of-sight to the interrogator is not required.

♦ Location Finding Capability. By outfitting an area with interrogators, wide area inventories can be taken. Interrogators are instructed to read tags and then data from all interrogators can be fed into a host computer where data can be stored, processed, and/or analyzed. The system software can determine the proximity of a tag between several interrogators permitting its location to be identified in respect to the interrogator receiving the strongest signal.

♦ Interrogators. Tag systems can be operated with either fixed or portable omni-directional interrogators.

▲ Fixed interrogators are typically placed at entry/exit points to facilities to identify movement in or out. Additional fixed interrogators can be mounted throughout facilities to provide complete coverage of an area for wide area inventory and asset management functions. In enclosed facilities, a single antenna will cover an area of 10,000 square feet. For open storage, a single antenna will support an area of 2.5 acres.

▲ Portable interrogators have been developed to work in place of a series of fixed interrogators. They provide the capability to move through facilities and read tags as they come within reading range. Read range for portable interrogators is less than that of fixed versions.

F. VIABLE MITLA/RF APPLICATIONS

The infusion of RF technology shows unlimited potential for the Marine Corps in many functional areas. The family of RF/AEI tags can be modified and integrated into existing LOGAIS systems to provide the following support capabilities: asset tracking, cargo manifesting, security, environmental sensing, and equipment maintenance management.

The basic version of the RF tag supports container tracking, container manifesting, and inventory management. A tag is attached to an item, such as a container or vehicle, to identify an asset and its location. A modified version of the tag can be used to support container manifesting. Essentially, as containers are loaded with materials, the contents can be recorded on a PC and upgraded to support RF/AEI using a LOGMARS-type application. The Marine Corps' standard PC, used to support MAGTF LOGAIS, could be configured and employed to upload/download inventory records to tags. This procedure, which can be accomplished on demand, can update tags to reflect current asset inventory. Conversely, as inventory is withdrawn, tags can be debited to support inventory management.

The security tag, a modified version of the basic commercially available system, has been developed to provide a capability to monitor container security. This tag is an upgraded tag outfitted with a fiber optic loop that passes through the locking mechanism of the container. When the lock is opened the fiber breaks and the tag records the date and time of the security violation. When the container passes in or out of a check point, an interrogator checks the tag's status, reads it as violated, and sounds an alarm. Additionally, these tags can communicate with interrogators to sound an alarm if the container is broken into. With proper placement of either permanent or portable antennas, security personnel can monitor a marshalling yard or staging area from a central station.

Another modified version of the commercially available tag can provide environmental support management to enable a system to read and monitor ambient conditions within containers, storage areas, or other facilities. For example, on refrigerated containers, a sensor tag can be mounted to the refrigeration unit to measure temperature changes and generator fuel/oil levels. Should performance be outside established ranges, the incident can be recorded and an alarm sounded, as with the security tag.

Finally, the basic tag is ideally suited to store maintenance records of major end items or subassemblies as they move through maintenance processes or in storage awaiting issue. With the capacity to both read and write to tags, "maintenance records" can be updated to reflect equipment status changes. For items requiring scheduled PM, modification, and calibration, all pertinent data can be stored on the tag. For items inducted into depot maintenance activities, tags provide a method to track locations and statuses of subassemblies as they move through the maintenance cycle [Ref. 21: Encl. 1: pp. 3-4]. Chapter IV will further develop potential maintenance applications and integration strategies for MITLA RFID technology.

IV. INTEGRATION STRATEGIES

A. GENERAL

The most critical factor in OMFTS and maneuver warfare is to "get the right thing, in the right place, at the right time." Supporting this requires equipment be identified, tracked, and maintained along logistics lines to sustain force readiness. Traditionally, the CSS maintenance community has accomplished this by attaching a manual paper Equipment Repair Order (ERO) to PEIs and/or central components. From there it is hoped that EROs remain with equipment throughout maintenance and storage – usually they do.

During the mid-1980s, the CSS supply community was introduced to advanced technology; barcodes could now provide equipment with a "license plate," an identification tag that a computer can read for a machine or operator. Awkward and difficult routine work tasks were left to machines, and operators were given more advanced, skilled tasks. Supply efficiency, accountability, and readiness increased. Barcodes do, however, have limitations. They can only accommodate a small quantity of information; data cannot be changed, dependency on a master computer increases, and they are sensitive to dirt and heavy handling.

RFID and portable database systems provide a new alternative to CSS information challenges. Small, durable, flexible data modules with sizeable memory capacity provide efficient mini-read/write data files for each PEI. By lifting files from supporting CPUs and information from manual forms/records, logisticians now have the capability for each PEI to be intelligent and carry its own data while being stored, moved, and maintained. Communications between devices and LOGAIS applications, such as maintenance/supply management systems, now become easier because they are reading and writing common data in a common format.

B. EXISTING TECHNOLOGY AND PROCESS FLOW

The MAGTF Deployment Support System (MDSS) is used for unit level tracking. This system is an AIS designed with the capability to provide a commander with near real-time visibility of PEIs and major systems throughout an MPF operation. The system uses scanners that scan and record information contained on barcodes attached to equipment. Scanned data elements usually include the time, location, and equipment identity (note the absence of any maintenance information). However, exercises have shown that although this system is conceptually sound, it has not been effective as a tool for gauging either off-load status or throughput status during an operation. [Ref. 17: p. 25]

Factors identified as contributing to the ineffectiveness of the LOGMARS/MDSS-II system include:

- Incompatible system databases used throughout MPF operations.

- Extensive training and cohesiveness required for support personnel.

- Labor intensive reentry of unit-level information to accommodate interface with non-USMC LOGAIS systems.

- Improper system implementation such as disjointed arrival of LOGMARS equipment, poor scanning point positions, and lack of information about whether scans were successful.

- Equipment operation failure due to bright sunlight, dirt, and grease buildup on barcodes/scanners.

As elaborated in Chapter II, MIMMS-AIS is used to track Marine Corps maintenance work-in-process, and, with MARES, provides commanders and logisticians with maintenance/ readiness visibility. However, as also addressed earlier, these systems do not support equipment modification management and PM scheduling/status reporting. Additionally, the current system only marginally sustains a commander's maintenance management requirements for areas other than modification/PM. This dissatisfaction is clearly highlighted in the results of a "questionnaire-type" survey conducted by the authors.

The MITLA/RF survey, as shown in Appendix G, consisted of a cover page and a series of questions designed to elicit a respondent's (1) satisfaction with current maintenance management systems, (2) position regarding MITLA/RF's application to modification/PM, and (3) recommendations regarding other (if any) technologies requiring investigation. The survey was distributed at the Marine Corps' 1993 Biennial Maintenance Management Conference and was preceded by a detailed MITLA concept briefing given by HQMC I&L representatives. Conference attendees represented all major USMC logistic activities, bases, and fleet commands, and consisted primarily of logistics and maintenance officers. Each of the twenty-three attendees was given a survey after the HQMC briefing and the results are summarized as follows:

♦ Concerning satisfaction with tracking/recording maintenance in garrison, on a scale of one through ten where one represented "Not Satisfied" and ten "Extremely Satisfied," the average response was 3.2 (see Figure 4.1).

♦ Relative to satisfaction with tracking/recording maintenance when deployed, on a scale of one through ten where one represented "Not Satisfied" and ten "Extremely Satisfied," the average response was 2.7 (see Figure 4.1).

♦ 77% of respondents suggested that modification control and PM scheduling should be the "point of entry" for introducing MITLA/RF into the maintenance community; however, a common thread was a concern that any improvement in maintenance management operations address LOGAIS compatibility, flexibility, and near real-time data throughput when deployed.

♦ When asked to rank several fundamental issues regarding MITLA/RF implementation, respondents indicated that workload reduction and system reliability should receive the principal focus (see Figure 4.2).

♦ Alternatives for MITLA/RF application to maintenance operations encompassed a host of recommendations to enhance current procedures. Suggestions included using MITLA/RF for eliminating all maintenance forms/records, tracking work-in-process (WIP), dispatching equipment, controlling repair parts, storing and accessing technical manuals, and simplifying operations through augmentation with other technologies (smart cards, barcoding, CD-ROM, etc.).

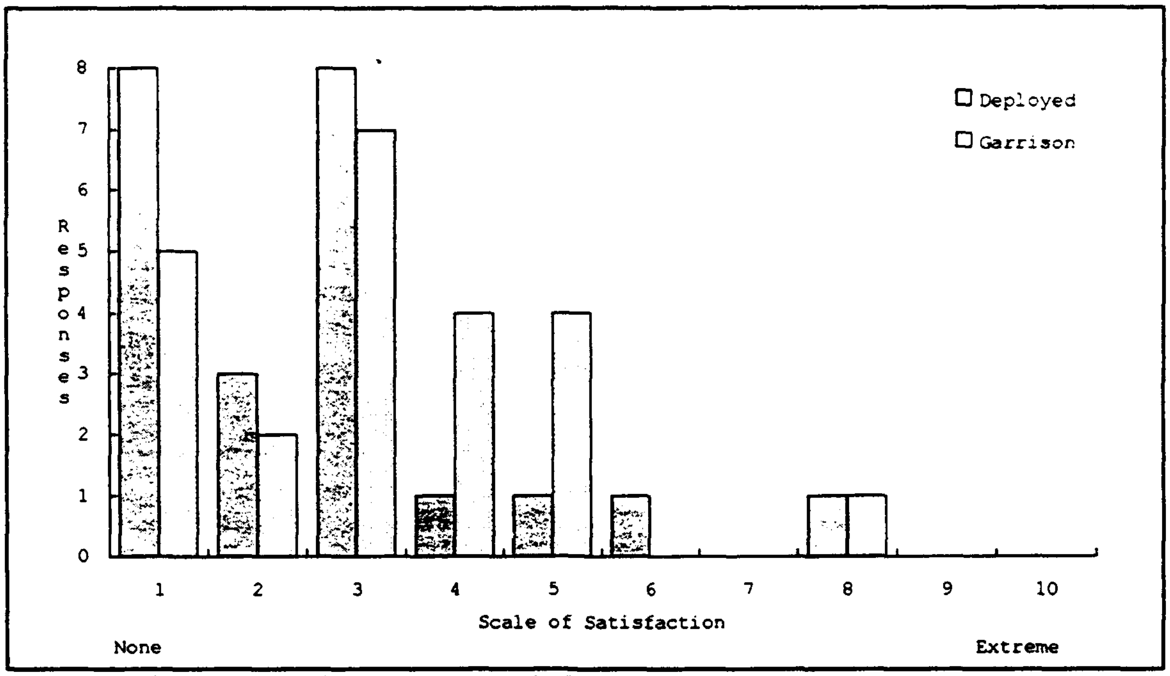

FIGURE 4.1 – Satisfaction With Maintenance Mgmt Systems

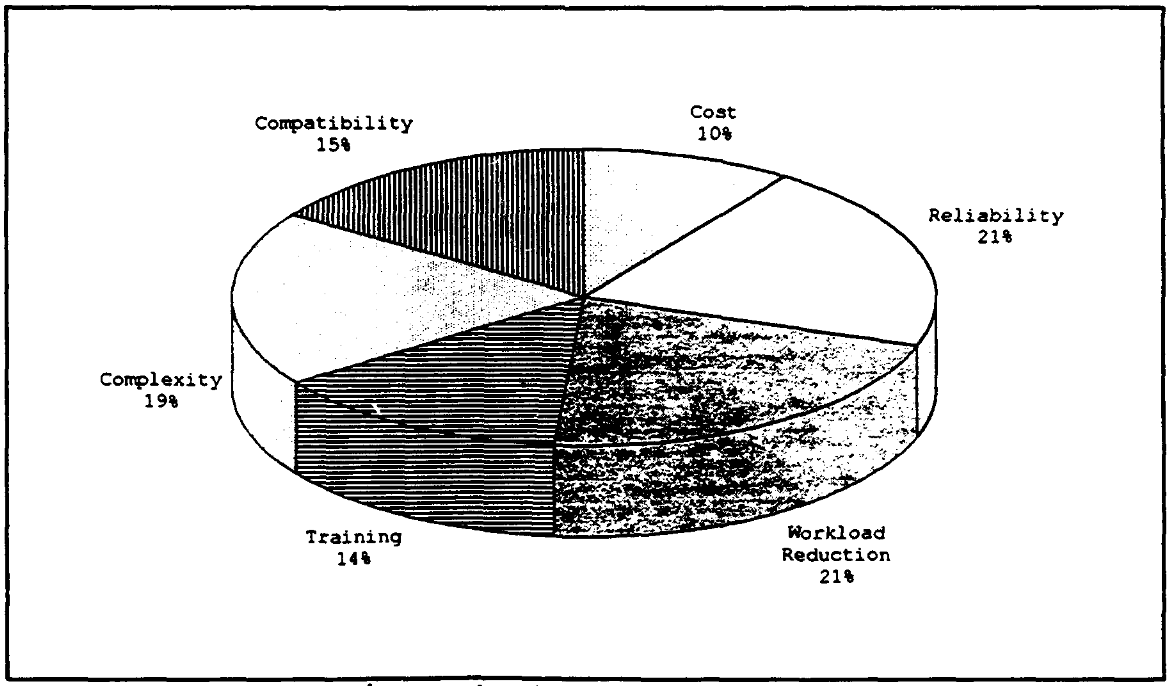

FIGURE 4.2 – MITLA/RF Priorities

C. OPERATIONAL CONCEPT

The envisioned operational concept is to attach transponders or tags to PEIs enabling them to remotely "hear", "respond", and "talk" with C^4I^2 systems. Logistics information will be attached to PEIs and automatically reported to C^4I^2 systems with minimal human intervention. PEIs will be able to report what they are, who they belong to, where they are, and what their status is. The result will be "talking" and "intelligent" PEIs.

Information, incorporated into tags, will follow items and provide "escort" databases, thus eliminating lost information caused by limited access and disconnects to LOGAIS and destroyed equipment records. Since transponders will be fully integrated into C^4I^2 and supported by LOGAIS, they become a vital, near real-time link to pass information to commanders and other systems.

Tag information will be dispersed using modern distributed information management technologies into a family of planning and logistics systems that integrate funcitional areas of planning, supply, transportation, embarkation, and maintenance. Such a system will go on to aggregate data from the small unit level up to joint commands. These technologies and systems will be used to provide rapid, robust, and dynamically reconfigurable LOGAIS systems that will rapidly process and distribute information. The net result is that command and control will be extended down into the logistics systems and to the PEIs themselves. The resulting capability will provide commanders and logisticians information on the location and status of every item, whether in storage, in transit, in maintenance, or on the battlefield.

The functional management responsibility for MITLA/RF, as it pertains to capturing maintenance data, PEI accountabilty, and equipment status, should fall upon logisticians. However, logistics information functions, as integrated into C^4I^2, should fall under the cognizance of the communications/electronics community (mirroring how logistics management and systems/database management responsibilities are now assigned). Accordingly, RF tags and data subsequently transmitted to logistics activities should be managed by the communications/electronics community. This concept should contribute to complete data compatibility and integration of logistics into tactical information systems, provide the capability for secure communications, and permit storage of aggregate classified logistics information. [Ref. 18: p. 3]

D. MITLA/RF SYSTEM DATABASE

During the Marine Corps' MITLA/RF container visibility evaluation, the prototype database was initialized with the following asset data: (1) equipment category, (2) asset type,

(3) equipment owner, and (4) assest ID. When the above data was entered into the database, RF tag IDs were assigned to PEIs. Asset data did not reside in the RF tags; it resided in the system database on the central computer.[7] However, this structure was a function of memory capacity. As tag capacities increase, asset data can be selectively downloaded to ease equipment transfer beyond the reach of supporting central computers. [Ref. 22: p. 10]

The methods used in structuring data on MITLA/RF tags can greatly affect the performance of supporting LOGAIS systems. As data storage requirements become greater, and more information is carried with PEIs, data required for logistic functions could become noncontiguous and the need for multiple access to tags may become necessary - thus slowing system throughput. It is important that the most frequently read data be put in consecutive order to prevent excessive cycle times resulting from too many reads or writes within one cycle. There is almost an infinite number of uses for tag memory, and with memory capacities increasing as envisioned, the only restriction to data size is the cycle time of the supporting system. [Ref. 4: pp. 4.39 - 4.41]

[7] The SAVI TyTag which was used during the evaluation had a 128 character memory capacity.

Concerning modifications and PMs, an MITLA/RF central database should provide information to accurately identify: (1) the basic supply elements listed above, (2) required and completed modifications, and (3) required PM services. Data should simply provide modification status and streamline the generation of PM schedules (i.e., quarterly, semiannual, annual, biennial, triennial, etc.). As described above, MITLA/RF data should be available for tag downloading whenever equipment is transferred to MAGTF units, retrograded/evacuated to maintenance activities, or loaned to other units for short-term use; it should not be necessary to maintain this information on RF tags indefinitely. Thus, any unit supported by MITLA/RF can quickly and accurately evaluate modification/PM status without a herculean effort to locate, reconcile, or generate required forms/records.

Once "obsolete" forms, such as modification control and preventive maintenance records, are streamlined by the logistics community to identify only the most critical elements, information can be easily translated into a PC-type database requiring only routine data entry skills. To minimize the learning curve for data entry clerks, data parameters would simply mimic current form entries and avoid new terms/concepts. It can also be anticipated that the same data entry clerks now entering "maintenance-in-process" information will also be tasked to input modification/PM data which will minimize overhead, training, and "growing pains." These automation efforts could be integrated into forthcoming systems such as the Asset Tracking Logistics and Supply System (ATLASS) negating the requirement for additional supporting system/hardware platforms.

E. SYSTEM INTERFACES

MITLA/RF hardware makes near real-time, actual status and tracking of assets possible. However, what truly adds value to the MAGTF's CSS functions is this system's ability to interface with other LOGAIS, integrate maintenance management data derived therefrom, and link it with hardware provided data, then subsequently generating user-defined reports for decision making. Ideally, MITLA/RF systems should not supplant current tools for logistics management. Rather, its purpose should be to enhance their performance through integration and communication among CSS information systems.

Current systems such as MDSS II and the Landing Force Asset Distribution System (LFADS) provide MAGTF commanders the capability to manage and distribute supplies/equipment from data assumed to be accurate. However, these systems do not show MAGTF commanders the near real-time physical status and location of PEIs that may be required immediately. This capability is a primary feature of RF tag technology. Data collected through MITLA/RF will be passed to and processed by appropriate LOGAIS component systems more quickly than can be achieved by handwritten records or LOGMARS-type scanning devices. This will provide MAGTF commanders and subordinate element commanders more current and accurate decision making information.

LOGAIS represents a logical resource to integrate data, test interfaces, and confirm design requirements for RF applications necessary to support MAGTF commanders. MITLA/RF will enable LOGAIS users to rapidly access maintenance management data through interfaces and interaction with systems such as: ATLASS, MDSS II, LFADS, Transportation Coordinators' Automated Information for Movements System (TC AIMS), LOGMARS, and the MAGTF Data Library (MDL).[8]

A synthesis of MITLA/RF with the future ATLASS system, a system designed to develop a new way to conduct ground maintenance and supply at unit and intermediate levels, may be the ideal solution. This synthesis is particularly inviting because ATLASS will not only replace MIMMS, MARES, Supported Activities Supply System (SASSY), Medical Logistics System

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[8] MDL consists of a database comprised of standardized manpower and materiel-related files from which source data sets are created for use in the LOGAIS family of systems. For detailed specifications on the Marine Corps' prototype designs concerning operating/communication systems, Structured Query Languages (SQL), and Relational Database Management System (RDMS) parameters, refer to the USMC Prototype Initiation Report [Ref. 12: p. 2-3].

(MEDLOGS), and the Ammunition Logistics System (AMMOLOGS), but will also enhance current interfaces with the LOGAIS family of systems [Ref. 23: pp. 11-12]. Further, this symbiotic relationship has the potential to greatly advance the integration of various maintenance management functions, both horizontally and vertically.

F. A MAINTENANCE MANAGEMENT "GAME PLAN"

RF technology can be used in maintenance management operations to perform a variety of administrative, historical record keeping, and asset tracking functions. It is helpful to think about tags being partitioned into distinct segments as is common on hard disk drives on PCs. These segments can then be used for various purposes. One segment could be used to contain basic "data plate" type information. This would allow reading vehicle specific data (such as serial number, nomenclature, etc.) but not changing it. This would ensure that data would not accidentally be changed or erased. In effect, this portion of a tag would provide constant, consistent source data automation specific to PEIs. It would also serve to simplify source data automation for other applications. [Ref. 24: p. 22]

An organization owning a vehicle could use the read/write portion of a tag to enter unit specific data as well as any record book/hand receipt information that may be required.

Tags could also store unit and organizational maintenance information. This would allow units to perform such operations as "polling" their motor pool to determine which vehicles require scheduled maintenance/modifications thereby reducing requirements for "normal" paperwork. It could also include operator comments, operational status, etc. Fixed interrogators mounted at entry and exit points could provide dispatchers with automatic updates for vehicle dispatch and return. Forms and records that may be considered for such automation could include the following:

- Oil Analysis Log (DA FORM 2408.20)
- Inspection/Repair Tag (NAVMC 1018)
- Equipment Repair Order (NAVMC 10245)
- Daily Dispatching Record (NAVMC 10031)
- Preventive Maintenance Roster (NAVMC 10561)
- Limited Technical Inspection Record (NAVMC 10284)
- Equipment Repair Order Shopping List (NAVMC 10925)
- Vehicle/Engineer Equipment Record Folder (NAVMC 696)
- Modification Control Records (NAVMCs 11053 and 11054)

Tags can also provide a source of data to organizations outside of equipment owners. When tagged equipment is turned in for second or higher echelon repair or services, information required to build a maintenance ERO could be captured from a tag either as equipment enters a maintenance area or on an as required basis by using hand held interrogators. RF connections between hand held devices and supporting LOGAIS would also allow maintenance inspectors to enter their initial analysis, or trigger a request for parts to perform required work. Tags could be updated by maintenance personnel to indicate work performed. When equipment is released back to owning units, its passing back into unit areas could be recorded by interrogators reading and reporting arrival data. [Ref. 24: p. 22]

Along with maintenance history, tags could also carry details about PEI "indentured" relationships. This would serve as a source for ensuring that the proper serial numbered component items (i.e., gun tube, night vision devices, radios, etc.) remain with or are returned to the proper parent item after they have been repaired/serviced. [Ref. 24: p. 22]

Implementing these local concepts addresses only half the maintenance management challenge. Not only is it imperative to automate archaic record keeping and provide near real-time data flows "upstream," but it is equally important that MITLA/RF serve as a springboard for timely, easily malleable, and concise "downstream" flows of information. Subjects such as modification instructions, RCM notices, directives and technical publications (issues/revisions), warranty information, maintenance management policy notices, Weapon System/Equipment Manager (WS/EM) Alerts, etc., must begin to take advantage of the emerging "electronic highway." To unite the efforts of those in the "trenches" and decision makers several echelons away, maintenance management procedures must be streamlined, automated, integrated, and interactive – horizontally, vertically, and globally.

V. CONCLUSION, RECOMMENDATIONS, AND FINAL REMARKS

A. GENERAL

This thesis presents the background, criteria, recommendations, and a proposed plan of action for pursuing a maintenance management/RF technology initiative. The infusion of RF technology shows unlimited potential in many functional areas; specifically, maintenance management is a prime candidate to expeditiously capitalize on this technology. Additional focus is given to the current need for managing maintenance, as supported by MITLA/RF technology, within emerging OMFTS concepts. This document offers a framework to satisfy these objectives.

The initial departure point is to identify specific requirements and streamline/optimize current maintenance management procedures and doctrine. Then, an integration effort must focus on a critical path to infuse RF technology within the existing foundation of LOGAIS and the general infrastructure (policy, existing hardware, and standards), while documenting other RF technology applications that will best serve the long range needs of the right-sized Marine Corps. At a minimum, any effort should also consider RF technology as an enhancement and extension of functionality for LOGAIS to support the FMF.

The plan should also capitalize on the utility and technology already existing within these systems and in the Marine Corps. RF technology is a platform that will allow the Marine Corps to efficiently address this requirement with state-of-the-art processes and well-organized procedures. As technology expands and requirements change, the Marine Corps must have an automated process that is cost efficient, reliable, and acceptable to an open systems concept.

B. CONCLUSION AND RECOMMENDATIONS

Data on maintenance management processes, to include both successes and shortfalls, were obtained from the authors' extensive fleet experiences, written surveys, and discussions with individuals in the FMF, HQMC, MCLB Albany, NCEL, and SAVI Technology. The data collected suggests that CSS cannot continue to be responsive using antiquated record keeping procedures and compartmentalized information networks when faced with the increased tempo, mobility, and distances associated with OMFTS. Significant improvements must be made in the ability to provide WIP visibility, unit level tracking of assets and their operational status, collection of RCM-type information, and reduction in the work force required to record and maintain maintenance transactions.

The recording and tracking architecture discussed in this thesis offers alternatives to reliance on manual record keeping, explores several near real-time interactive decision making tools, and suggests doctrinal improvements through a fusion of procedural and high-tech approaches – it is a study proposing an outline for melding policy change with the state-of-the-art technology to successfully support emerging CSS operations. The tracking portion of the architecture is a combination of a family of RF tags and a corresponding family of interrogators. RF tags address an array of capabilities that, when used with each other, meet the objectives of WIP visibility, asset tracking, RCM data collection, and reduced labor requirements. Tags vary in memory capability, programmability, cost, and ability to communicate with other tags within the architecture family. Interrogators have a similar range of capabilities, cost, and communication ranges.

The recording portion of the architecture, through an internet paradigm, provides the foundation for all system component tags and operating systems to exchange information. This basic concept envisioned the simple automation of manual forms/records into a database-type structure managed by systems such as ATLASS, LOGAIS, etc. The internet paradigm should have a flexible format, providing expandability and scalability for long range planning. The internet paradigm will allow tags, thus items and units, to respond/originate messages regarding their status and provide for a seamless information flow across organizational boundaries.

Current automatic identification technologies are also addressed in this treatise. To capitalize on Marine Corps R&D initiatives, and their inherent capacity to satisfy maintenance management shortfalls, RF tags, as they exist today, could serve as a point of departure for needed LOGAIS integration. Presently, RF tags can only operate locally with no general communications capabilities. Extending these capabilities as addressed in this study and outlined in Figure 5.1 will give tags the ability to operate globally in a dynamic environment – making the system deployable and a viable CSS component.

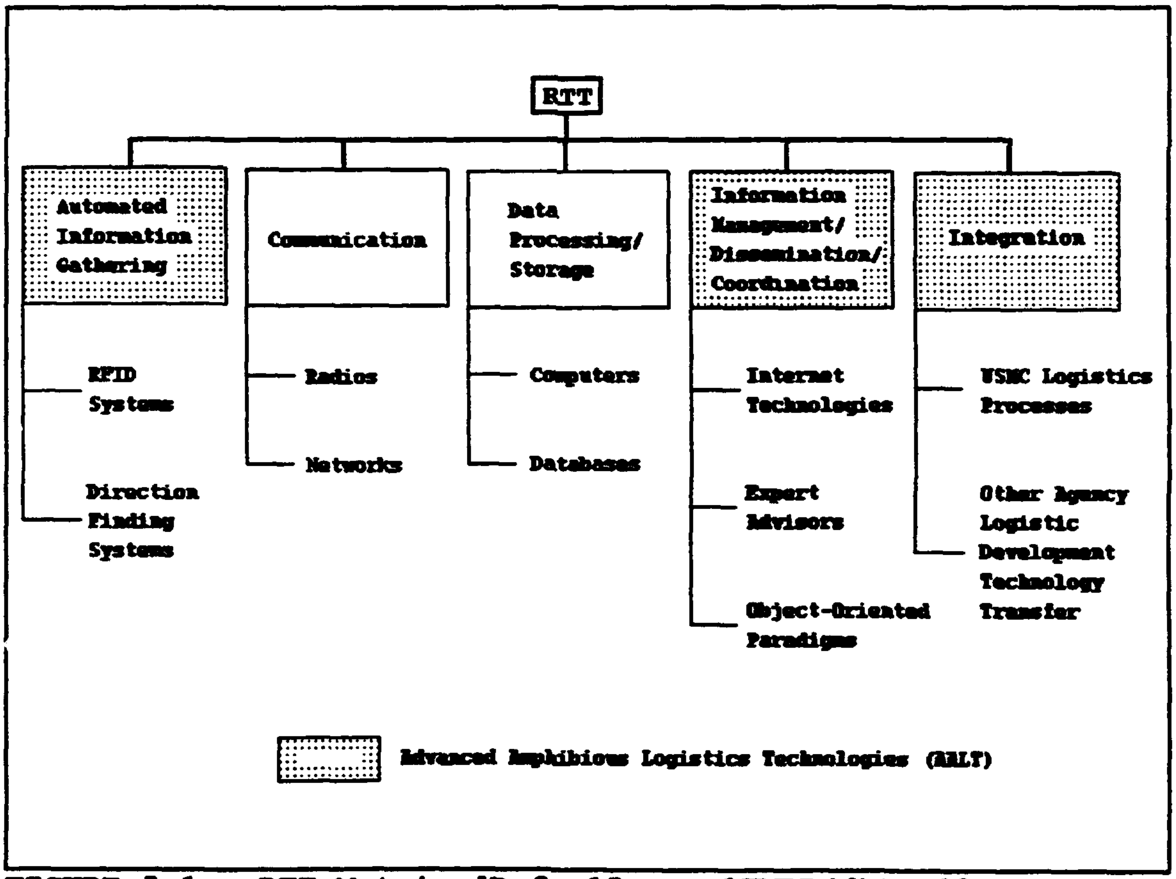


FIGURE 5.1 – RTT Matrix [Ref. 15: p. 1KMBB(d)tm.1]

The primary focus for any deployment of Marine Corps forces is the performance of a specific mission, and all activities associated with deployment must be assessed in terms of how effectively they support the successful execution of that mission. Within the Marine Corps the key component for execution of the mission is the tactical maneuver element. Therefore, the logistics train, should, theoretically, be tailored to optimize support of the maneuver element.

Effective logistics support means (1) getting what is needed, when it is needed, and where it is needed, and (2) maintaining sufficient flexibility to minimize operational constraints due to limitations in logistics support. Obviously there are limitations on resources, personnel, and transportation assets that preclude meeting every conceivable contingency. There are, however, ways to restate these goals in reasonable and realistic terms that apply directly to the logistics and maintenance process:

♦ Streamline and redefine maintenance management doctrine in support of dynamic force structures and OMFTS concepts.

♦ Reevaluate current maintenance record requirements/information, determine specific reporting/tracking needs, and automate the collection/maintenance of the information.

♦ Collect, transmit, process, and integrate maintenance management data with all supporting LOGAIS systems, through AIS/AIT (such as MITLA/RF).

♦ Provide decision makers, at every organizational level, access to "live" maintenance management information.

♦ Enable the force to sustain its CSS mission objectives in a reduced work force environment.

Additionally, with the achievement of these objectives and MITLA/RF implementation, maintenance operations could capitalize on the following opportunities. For instance, applying MITLA/RF to PM would provide a significantly better monitoring system leading to a reduction in CM requirements. In this scenario, demands for spares decreases, inventory systems respond more quickly, maintenance forecasting models improve, mechanics focus on "wrench-turning" vice paperwork, and PEI operational availability increases. Furthermore, replacing/improving other maintenance records with MITLA/RF could reduce diagnostic and repair time (quicker turn-around-time). In summary, implementation of MITLA/RF would contribute to more responsive inventories, better use of supply/ maintenance personnel, and higher operational readiness at lower maintenance costs.

However, before these goals and the MITLA/RF concepts discussed herein can materialize, several significant limitations must be addressed: (1) accessibility to "real world" test/maintenance data, (2) availability of baselines for aggregate labor hours/costs expended during maintenance management functions, and (3) measurability of MITLA/RF'S "added value" to support maintenance and OMFTS operations. In the same vein, follow-on efforts are also required toward conducting cost/benefit analyses of MITLA/RF (as applied to a MAGTF or major subordinate command); programming the acquisition, life-cycle, and provisioning elements of the technology; generating RF tag database structures; and designing requisite LOGAIS interface modules.

As Lieutenant Colonel Johnson deftly states in his article, *State of the Art: Not So Fast*, the Marine Corps must ensure that the basic warfighting skills already mastered and proven without the aid of state-of-the-art technology remain intact and on standby. Advancements in technology have made the challenge of command and control much easier to meet, yet considerably more complex. Combat leaders today are faced with an overwhelming amount of data that must be stored, analyzed, and used to make complete, sound tactical decisions. High-tech developments in data processing have yielded incredible increases in the quantity and speed of data available to commanders. The difference between combat triumph and disaster is, of course, the quality of that information. The key issue in any future AIS/AIT development, to justify the effort, must be improvement in the quality of information available. It is essential that the Marine Corps continue to move forward in R&D; however, there must be a balance between the degree of sophistication that should be employed and what could be deployed – a balance in how far and fast the Corps moves in technology. [Ref. 25: p.44]

C. FINAL REMARKS

New concepts of operation and associated doctrine for employment of Marine Corps expeditionary forces are being developed to address future threat scenarios. These concepts of Over-the-Horizon (OTH) amphibious operations, and maneuver warfare (MW) represent a significant change in amphibious warfare. The OTH amphibious operation is a seaward extension of the Marine Corps' philosophy of MW; significant changes are required in the concepts of operations and equipment for CSS to sustain forward deployed maneuver elements. The Advanced Amphibious Logistics Technology (AALT) project, as chartered by the Marine Corps Research, Development, and Acquisition Command (MCRDAC), is designed to develop a plan for R&D between now and the year 2010 to provide operational systems and techniques for responsive CSS in an OMFTS environment. A key aim of the AALT project, with direct bearing on the scope of this thesis, is the plan to prioritize and schedule R&D for systems that will: [Ref. 26: p. 1]

- Simplify procedures and reduce costs associated with CSS functions.
- Enhance combat support capabilities with existing or reduced workforce levels and skill level requirements.
- Provide for interface of LOGAIS systems with interrelated areas, such as communications, intelligence, etc.
- Identify and develop technologies to expedite locating and transferring materials on an on-call or as required basis in support of deployed forces.
- Move large volumes of material, supplies, and equipment to combat units across shorelines and into forward areas faster than with existing capabilities.

Both OTH and MW operations preclude developing substantial CSS maintenance capabilities on shore. This suggests that echelons III and IV maintenance must be provided by (1) CSS personnel aboard a sea-based maintenance facility, (2) CSS personnel who are transported, along with necessary equipment, to the combat zone, or (3) unit maintenance personnel trained and equipped to provide a higher level of maintenance themselves. The "fixed forward" concept will require higher levels of maintenance be performed in the field, and increase transportation requirements for delivery of spare parts and perhaps CSS personnel. This increased transportation of replacement parts, including subassemblies, will further stress supply, transportation, and communications channels. This will only be heightened when supply is provided from a sea-based supply platform located OTH. [Ref. 26: p. 22]

A corollary to the "fixed forward" concept is the forward push of class IX (replacement parts) to maneuver units. This will help reduce time lags due to the requisition cycle, especially for replacing maintenance-related spares such as filters and batteries. "Consumption rates" of spare and other replacement parts must be accurately estimated from historical maintenance data, and be prepackaged, ready for supply to maneuvering elements. This directly feeds into the requirement for a knowledge-based supply/maintenance AIS, and a paperless maintenance WIP/spare requisitioning system to relieve maintenance personnel of administrative burdens and to elicit the responsiveness called for under the OTH/MW concept. [Ref. 26: p. 22]

Most Marine Corps CSS operations require using paper-based administration and tracking systems. The increased pace and flexibility integral to MW operations cannot be met by the current CSS paper and computer-based information systems. A new AIS for maintenance support needs to be developed with capabilities for (1) near real-time WIP visibility, (2) repair part requisition, shipment, logging, and tracking, (3) calculating updated projections of maintenance requirements (RCM-based), and (4) identifying equipment configurations and readiness postures. Without the ability to physically anchor maintenance assets at established Beach Support Areas (BSA), sea-based efforts must rely on the accuracy and "live" transmission of recorded maintenance/supply information. [Ref. 26: p. 24]

An automated means for determining exact maintenance requirements and status must be developed. Ideally, the method chosen should be directly interfaced with the supporting supply AIS. AIT should be exploited to develop this capability. To operate effectively, the system must remain simple to use and not produce additional "bookkeeping" tasks for maintenance personnel. Emerging technology, such as

MITLA/RF, now being considered by the Marine Corps' supply community for inventory management could make automating maintenance management procedures feasible and provide a springboard into OMFTS - 2010 and beyond.

APPENDIX A (List of Abbreviations)

AALT	Advanced Amphibious Logistics Technology
AASP	Arrival and Support Party
ADP	Automated Data Processing
AEI	Automatic Equipment Identification
AI	Artificial Intelligence
AIS	Automated Information Systems
AIT	Automated Identification Technology
AMMOLOGS	Ammunition Logistics Systems
ATLASS	Asset Tracking Logistics and Supply System
BAIT	Battlefield Automated Identification Technology
BIC	Blount Island Command (Jacksonville, Florida)
BPI	Bits Per Inch
BSA	Beach Support Areas
C^4I^2	Command, Control, Communications, Computers, Intelligence, and Interoperability
CD-ROM	Compact Disk – Read Only Memory
CIM	Computer Integrated Manufacturing
CM	Corrective Maintenance
CPU	Central Processing Unit
CRC	Cyclical Redundancy Check
CSS	Combat Service Support
CSSE	Combat Service Support Element
DoD	Department of Defense

DSS	Deployment Support System
EEPROM	Electrically Erasable Programmable Read-Only Memory
EPROM	Erasable Programmable Read-Only Memory
ERO	Equipment Repair Order
ES	Expert Systems
FCC	Federal Communications Commission
FMECA	Failure Modes, Effects, and Criticality Analysis
FMF	Fleet Marine Force
FMFPAC	Fleet Marine Force Pacific
FONS	Fleet Operational Need Statement
HQMC	Headquarters Marine Corps
GPS	Global Positioning System
I&L	Installations and Logistics
ICR	Image Character Recognition
ISMO	Information Systems Management Office
ITV	In-Transit Visibility
LAN	Local Area Network
LEO	Low Earth Orbit
LFADS	Landing Force Asset Distribution System
LMCC	Logistics Movement Control Center
LOGAIS	Logistics Automated Information Systems
LOGMARS	Logistics Applications of Automated Marking and Reading Symbols
LORAN	Long-Range Navigation
LTI	Limited Technical Inspection
MAGTF	Marine Air-Ground Task Force

Mb	Megabyte
MARES	Marine Corps Automated Readiness Evaluation System
MCLB	Marine Corps Logistics Base
MCRDAC	Marine Corps Research, Development, and Acquisition Command
MDL	MAGTF Data Library
MDSS	MAGTF Deployment Support System
MEDLOGS	Medical Logistics System
MEF	Marine Expeditionary Force
MHz	Megahertz
MI	Modification Instruction
MIMMS	Marine Corps Integrated Maintenance Management System
MITLA/RF	Microcircuit Technology in Logistics Applications/ Radio Frequency
MCO	Marine Corps Order
MPF	Maritime Prepositioning Force
ms	millisecond
MS DOS	Microsoft Disk Operating System
MTBF	Mean Time Between Failure
MW	Maneuver Warfare
NATO	North Atlantic Treaty Organization
NAVMC	Navy/Marine Corps
NCEL	Naval Civil Engineering Laboratory
OCR	Optical Character Recognition
OMFTS	Operational Maneuver From The Sea
OTH	Over-the-Horizon
PC	Personal Computer

PEI	Principal End Item
PIN	Personal Identification Number
PM	Preventive Maintenance
RCM	Reliability Centered Maintenance
R&D	Research and Development
RDMS	Relational Database Management System
RF	Radio Frequency
RFID	Radio Frequency Identification
ROM	Read-Only Memory
RPV	Remotely Piloted Vehicle
RTT	Recording and Tracking Technology
SASSY	Supported Activities Supply System
SBIR	Small Business Innovative Research
SQL	Structured Query Language
SRAM	Static Random Access Memory
TC AIMS	Transportation Coordinators' Automated Information for Movement System
TM	Technical Manual
TPFDD	Time Phased Force Deployment Data
WAN	Wide Area Network
WIP	Work-in-Process
WORM	Write Once, Read Many
WS/EM	Weapon System/Equipment Manager (Alert)

APPENDIX B (List of Key Terms)

Artificial Intelligence/Expert System (AI/ES). The science of making machines do things that would require human intelligence. An expert system is an intelligent computer program that uses knowledge and inference procedures to solve difficult problems that would typically require significant human expertise for solution. Knowledge necessary to perform at this level, together with the inference procedures used, model the "best" practitioners in the related field.

Automatic Equipment Identification (AEI). A system that uses RF transmissions to collect and transfer specific equipment identification data. An AEI system consists of AEI tags (one per item) and AEI reading devices. As an item is brought within range of a reader, the reader interrogates the tag and can read/write information as required. This information can then be relayed to the system's host computer for storage and processing.

Barcode Template. A list/menu of specially prepared barcodes representing specific data to be read by a scanning device and interpreted on a display terminal.

Byte. Number of bits (binary digits) representing a character for use in software or hardware manipulation. There is typically eight bits to a byte.

Contact Tag. A microchip tag which requires physical contact with a reading device for the transfer of data.

Data Collision. Interference caused by the attempt of an RF antenna to receive radio signals simultaneously from more than one source. Requires programming of software protocols to regulate reception and processing of radio signals.

Data Integrity. The degree of accuracy to which data transmitted by RF signal is received and interpreted by a reader.

Echelons of Maintenance. There are currently five maintenance echelons within the USMC maintenance support function. The first echelon is maintenance performed by the equipment operator. This is normally preventive in nature. Second echelon maintenance is performed by trained mechanics located within the organization. This echelon is responsible for extensive PM and limited component/part replacement. Third echelon maintenance is performed by specially trained personnel, sometimes found within an organization, but often located at a centralized maintenance site. Third echelon mechanics are responsible for repairing subassemblies, component exchange, and calibration. Fourth echelon maintenance is performed by CSS elements. This level is involved with end-item overhaul and component repair. Fifth echelon maintenance performs major rebuilds in industrial type facilities.

Electronic Data Interchange. A standard technique used to exchange business information via electronic means. The information may be a financial business transaction, an inventory replenishment order, order entry, an invoice, a payment, drawings, E-mail, etc.

First Read. The occurrence of receiving and accurately interpreting an RF signal on the first attempt. First read consistency is the maximum distance between tag and reader that a signal is received and accurately read on the first attempt.

Flash Memory. Electronic memory that provides high-speed, nonvolatile storage of programs or data. Whatever is recorded onto flash memory stays in the memory chip, even if the power is turned off. To record over a previously used area, a higher voltage is directed to the memory address, clearing the data. This area can then be used again for storage.

Interrogator. A tripod/ceiling mounted radio transmitter and receiver that relays data between RF tags and a system's host computer.

Laser Card. A technique of optically encoding/decoding information on a heat sensitive stripe via laser. This moderately expensive optical technology allows text, graphics, or digitalized sound to be stored and retrieved from a credit card sized housing media. Very closely related to Write-Once-Read-Many (WORM) technology.

Logistics Applications of Automated Marking and Reading Symbols (LOGMARS). Technology that employs machine-readable symbology (such as barcodes) and a scanning device that is able to read this encoded information. This information is then relayed to a database for further analysis.

Magnetic Stripe. A generic term applied to an inexpensive structured information storage/retrieval methodology. This methodology is characterized by a magnetic stripe attached to a credit card housing and the capability to store a low volume of information.

MAGTF Deployment Support System (MAGTF/DSS). An automated unit-level deployment planning and execution system that provides MAGTF's and their subordinate elements the ability to develop plan specific force structures (personnel, supplies, and equipment). At execution, the system provides near real-time retrieval of information in the form of reports, listings, or data sets for export to other systems.

MAGTF II. A microcomputer based system that modernizes the Marine Corps' war planning capability. This system will support crisis and deliberate planning, TPFDD generation, and produce gross air and sealift estimations.

Memory Card. Credit card sized microchip, static random access memory (SRAM) technology mounted in a removable media. The memory card is reusable, does not contain a processor, and currently has approximately four megabytes of memory capacity.

Microchip Tag. The generic term applied to small electronic devices that can receive/store data and are readable by remote receivers. Microchip tags include contact/near contact and active/passive configurations.

Multipathing. The phenomenon that occurs when an RF signal reflects off an object enroute to the reader. Such anomalies can cause either a signal enhancement or erroneous reading.

One Dimensional Barcode/Two Dimensional Barcode. One dimensional barcode is a generic term applied to numerous variable length structured information encoding symbologies. This optically-based symbology is characterized by printed bars/spaces and a capability to encode low information volumes in a given space. Two dimensional barcode is a generic term applied to multi-row, continuous, variable length, structured information, encoding symbologies. This optically-based symbology has the capability to encode more information in a smaller space than the one dimensional barcode. Current one dimensional bar coding hardware will not read two dimensional barcodes. Once arrayed, the encoded data cannot be changed.

Optical Character Recognition (OCR) and Image Character Recognition (ICR). These techniques optically decode printed information. This optical technology allows both text and graphics to be read and manipulated by host computer software.

Radio Frequency Devices. A generic term applied to numerous unstructured information encoding technologies characterized by several attributes, including read/write distances, storage capacity, storage capability, and power sources. These devices do not require direct contact with an interface unit. Current storage capacity varies from 24 bits to 64 kilobytes. If the source of power is an onboard battery, the device is referred to as an active device. If it draws its power from the radio frequency waves of the transmitting unit, it is referred to as a passive device. These units may contain a separate microprocessor.

Reader. A device containing the electronics for the reception of an RF signal and its conversion into digital data. The reader may display the data/information or relay it to a computer.

Robotics. A branch of AI/ES concerned with enabling computers to "see" and "manipulate" objects in their surrounding environment. Uses heuristics to function in a highly flexible manner while interacting in a dynamic environment.

Read Only Memory (ROM). Memory that contains permanently stored data. This data can not be changed; however, it can be read multiple times.

Slave/Master Tag. A combination of tags hardwired together for use where extremely small microchip tags are required (eg. inaccessible locations.)

Smart Card/Integrated Circuit Card. A generic term applied to numerous structured information encoding technologies characterized by credit card sized media using Electrically-Erasable-Programmable-Read-Only-Memory (EEPROM). Often seen with a separate microprocessor, this technology has a low to medium information capacity and requires direct connection with a computer interface unit for information transfer.

Softstrip. A technique of encoding information that appears as a structured pattern of black and white rectangles. This proprietary development is similar to barcoding technology.

Speech Synthesis/Recognition. A generic term applied to numerous techniques that emulate human speech using computer hardware/software to translate text into recognizable speech. Speech recognition is a term applied to numerous techniques that emulate human hearing using computer hardware/software to translate sounds into machine recognizable text or actions.

Tag Discrimination. In tag configurations where multiple RF tags are located in close proximity to one another, software protocols provide the ability to differentiate between neighboring tags and avoid inaccurate transmissions.

Wedge. An electronic device inserted between a computer keyboard and a barcode wand/scanner to interpret barcodes and translate the coding into recognizable information.

APPENDIX C (Modification Control Records)

COMMODITY MANAGERS MODIFICATION CONTROL RECORD (FORM A) (4790)
NAVMC 11053 (8 79)
SN 0000 00 006 7660 U I SH

ACTION CODES		NOMENCLATURE / TAM NO / IDENTIFICATION NO
NA NOT APPLICABLE	C COMPLETED	TANK Combat w/M9 Bulldozer M60A1
PR PUBLICATION REQUIRED	V VERIFIED	TAM NO: E1876 XX
AR AS REQUIRED	ERO NUMBER	IDENTIFICATION NO: 672556
NOTE: ITEMS MARKED WITH AN ASTERISK (*) REQUIRE A JULIAN DATE		

MODIFICATION INSTRUCTION NUMBERS	CATEGORY	REQUIRED COMPLETION DATE	EQUIPMENT SERIAL NUMBERS: 264451	3999970	5910628	2399671	5754119	5921106	REMARKS
61348-35/1	U	28 NOV 82	C 2887	1398	C 2887	C 2888	V 1387	1398	
61348-35/1 CH1	U	28 NOV 82	C 2181	2148	C 2181	C 2181	V 2148	2148	
02525-35/10	U	8 OCT 81	C 0281	C 0281	C 1119	C 1119	C 0287	C 1181	
02525-35/4	U	24 AUG 79	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	w/CH 1,2
02525-35/6	U	2 OCT 80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	w/CH. 1
02525-35/7	U	19 OCT 80	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
02525-35/8	U	5 JUN 81	[illegible]	[illegible]	1118	[illegible]	[illegible]	[illegible]	
02525-35/9	U	26 AUG 81	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	
02525-35/1	U	18 SEP 79	[illegible]	[illegible]	[illegible]	9231	9231	[illegible]	w/CH. 1,2,3
02525-35/30	U	N/A	[illegible]	[illegible]	[illegible]		[illegible]	[illegible]	[illegible]
249738-35/1	U		PR	PR	PR	PR	PR	PR	[illegible]
249688-35/1	U	18 DEC 81	[illegible]	2011	2011	1182	2011	2011	

COMMODITY MANAGERS MODIFICATION CONTROL RECORD (FORM 8-4190)
NAVMC 11054 (8-79)
SN 0000-00-006-7880 U I SH

ACTION CODES	NOMENCLATURE
NA NOT APPLICABLE — C COMPLETED	TANK, Combat w/M9 Bulldozer M60A
PR PUBLICATION REQUIRED — V VERIFIED	TAM NO. 61826 XXX
AR AS REQUIRED — ERO NUMBER	IDENTIFICATION NO. 07585C
NOTE ITEMS MARKED WITH AN ASTERISK (*) REQUIRE A JULIAN DATE	

	MODIFICATION INSTRUCTION NUMBERS					
	01348-35/1	01348-35/1 CH.1	07585-25/10	07585-35/4 w/CH. 1,2	07585-35/6 w/CH. 1	07585-35/7
CATEGORY	U	U	N	U	N	N
REQUIRED COMPLETION DATE	26 NOV 82	26 NOV 82	2 OCT 81	24 AUG 79	2 OCT 86	19 OCT 86
EQUIPMENT SERIAL NUMBERS: 244431	C 2087	C 2181	C 0331	AR 9166	C 0216	C 0216
3999878	AR 1342	AR 2146	C 0331	AR 9166	V 0077	C 9306
5818630	C 2087	C 2181	C 1114	AR 9158	V [illegible]	C 9306
2319671	C 2088	C 2181	C 1114	AR 9166	C 0261	C 0331
5754119	V 1387	V 2146	C 0357	AR 9166	C 0286	C 0331
5921186	AR 1342	AR 2146	C 1161	AR 9166	C 0216	C 0216
REMARKS						

APPENDIX D (Preventive Maintenance Roster)

PREVENTIVE MAINTENANCE ROSTER (4790)
NAVMC 10561 (REV 10-86)
SN 0000-00-000-0204 U/I PD OF 100
(All previous editions of NAVMC 10561 and 10561A are obsolete and will not be used)

YEAR 86

ITEM NO	MODEL/ARMC NO	1	2	3	4	5	6	7	8	9	10	11	12
	TRACTOR ART STEER												
1	378 545	Q			Q			Q			Q		
2	329 123		Q			Q			Q			Q	
3	339 773			Q			Q			Q			Q
	TRACTOR PT CASE 1150												
4	333 278		Q			Q			Q			Q	
5	356 187	Q	Q			Q			Q			Q	
6	398 241			Q			Q			Q			Q

YEAR 87

ITEM NO	MODEL/ARMC NO	1	2	3	4	5	6	7	8	9	10	11	12
	TRACTOR ART STEER												
1	378 545	Q											
2	329 123		Q			Q			Q			Q	
3	339 773	Q			Q			Q			Q		
	TRACTOR PT CASE 1150												
4	333 278		Q			Q			Q			Q	
5	356 187		Q			Q			Q			Q	
6	398 241			Q			Q			Q			Q

YEAR 88

ITEM NO	MODEL/ARMC NO	1	2	3	4	5	6	7	8	9	10	11	12
	TRACTOR ART STEER												
1	378 545												
2	329 123												
3	339 773												
	TRACTOR PT CASE 1150												
4	333 278												
5	356 187												
6	398 241												

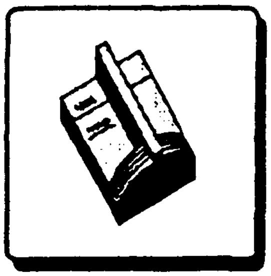
REMARKS

356187 SHT TECH 8602

339773 EQUIP NOT AVAIL 8701

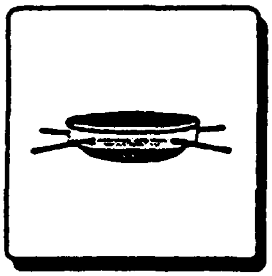
LEGEND B=BIENNIAL A=ANNUAL SA=SEMI ANNUAL Q=QUARTERLY (CALENDAR) H=QUARTERLY ([illegible] HRS) BM=BI MONTHLY M=MONTHLY L=LUBRICATION

APPENDIX E (TyTag System Components)



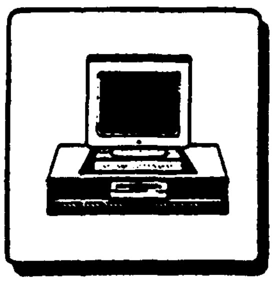
TYTAG

- Affixed to item
- Small radio transmitter/receiver
- Built-in memory
- 50-70 foot range



INTERROGATOR

- Ceiling-mounted
- Highly reliable radio transmitter/receiver
- Finds all tagged items in its area (cell)
- Reads/writes data to tags
- Sends data to central computer



COMPUTER

- Manages system communications
- Compiles data for inventories
- IBM PC-compatible
- Graphic user-interface

PORTABLE INTERROGATOR

- Hand-held interrogator
- Finds all tagged items in an area
- Reads/writes data to tags
- 4-line display and alphanumeric keypad
- Connects to computer to download data

APPENDIX F (System Component Descriptions)

Tags – Each tag type and its fundamental characteristics follows [Ref. 17: pp. 14-18]

Passive

Passive tags have no batteries and use incident RF energy for power and modifying/reflecting transmitter signals; readers must be held very close to the tags (i.e., inches) or use high power levels for greater distances, up to tens of feet; are like license plate numbers, with no associated intelligence; read only, cannot be changed after manufacture; limited fixed message length in tens of bytes; cost is very low, approximately fifty cents apiece; commercially available, and used for rapidly scanning items where barcodes are not appropriate, operating as an "electric barcode"; not as inexpensive as barcodes, however, they can be combined with them; and are small and environmentally resistant.

Beacon

These tags act as a beacon, with only a transmitter; are active devices always on and using battery power; operate up to tens of feet with no guaranteed receipt of their signals; do not acknowledge queries; also like license plates with no intelligence; read only capability and cannot be changed after manufacture; limited fixed message lengths, also in tens of bytes; cost is low, less than one dollar per tag; and are presently not commercially available, but could be used for marking and locating stored and hidden items.

Package

Package tags are like beacon tags but with small receivers for wake-up and acknowledgment; use battery power and operate up to tens of feet; have near perfect guarantee of signal receipt, greater than 90%; use a high power source or illuminator to activate, minimizing receiver costs; also like license plates with no intelligence; can be programmed and rewritten before application (i.e., one-way, read only tag after programming); limited message length, hundreds of bytes; inexpensive, approximately two or three dollars a piece; "matchbook" sized; and not commercially available at present.

Inventory

Inventory tags would be true smart tags, having bi-directional communication; contain a computer with rudimentary database capabilities; operating ranges from tens to hundreds of feet with near perfect signal receipt, 99.99% with acknowledgement; sensitive enough to pickup equally low powered signals from interrogators; require more expensive receivers; read/write capable; simple formatted database record and field capability; significant amount of non-volatile memory with hundreds, or thousands, of bytes; include sensors and sonic beepers for direction finding and location capability with direction finding interrogators; midrange costs, approximately $40 each; commercially available; nonruggedized, for use within warehouses, depots, maintenance facilities, manufacturing areas, and ships; and approximately the size of three packs of playing cards.

Ruggedized

These tags are the same as inventory tags but are environmentally sealed and ruggedized for military operations; include more memory, up to tens of thousands of bytes; able to store complete manifests or maintenance histories of PEIs; include capability to connect sensors for temperature, time, fiber optic breakloop (for security), weight, etc.; cost approximately $80 each; not commercially available; and approximately the size of eight packs of playing cards.

Database

These tags are the same as ruggedized tags, but with additional database engine capabilities; contain large memory capacities of over one-hundred kilobytes and have greater intelligence; can search internal stored contents and perform other simple database functions; tag IDs do not have to be known by interrogators, so they can be used to search for contents by NSN, or descriptive names; not commercially available; and cost approximately $100 a piece.

Relay/Database/Manifest

These tags are the same as database tags with the integration of small interrogators to read package inventories and ruggedized tags inside parent containers; provide automatic container manifesting and automatically update their own databases; can tell when something is added or removed from containers; not commercially available; and cost less than $250 each.

Long-Range

These tags are the same as ruggedized tags with high power transmitters and larger antennas to aid in locating items on larger bases; range is thousands of feet; may include LORAN (Long-Range Navigation) or GPS receiver; can be used on trucks and prime movers; has terrestrial intermediate radio communication; not commercially available; and cost between $200 and $350 each.

Battlefield Radio

These tags are the same as ruggedized, relay/database/ manifest, and long-range tags, but with the addition of two-way military battlefield digital radio communications; used for long-range battlefield applications, with miles of transmission range; gateway to terrestrial C^4I^2 systems and capable of talking with aircraft and loiter platforms; support spread-spectrum and encryption; not commercially available; and may be quite expense, depending on basic military radio costs.

Satellite

These tags are the same as relay/database/manifest and long-rang tags with the addition of a two-way satellite communication capability; will most likely work with LEO satellites to minimize transmitter power requirements and simplify antenna design; include GPS receivers, and are most suitable for ITV; world-wide coverage is achievable through delayed, batched communication; attached to prime movers and very high value assets; commercially available at very high cost of several thousand dollars for use with geosynchronous satellites; and for LEO satellites, anticipated costs are less than $500 each, however, LEO versions are not commercially available.

Internet

Internet tags are the same as relay/database/manifest, long-range, and satellite tags with the addition of Internet capability;[9] support Internet and/or DoD message formats; very

[9] The Internet paradigm is relatively new to computers and is maturing. The new C^4I^2 systems are based on this paradigm. All systems are peers and can exchange information with each other (with, of course, security restrictions). Information is exchanged in messages, rather than database records. The proposed idea is that tags can send and receive E-mail and human readable messages with other tags, interrogators, computer systems, databases, C^4I^2 systems, and message systems.

autonomous, can send/receive clear human readable E-mail and messages directly without translation; behave as hosts on the Internet; support ethernet/physical addresses; can directly interface with C^4I^2 architectures; no intermediate databases are required; not commercially available; the basis of the RTT advanced concepts and architecture; and do not presently exist in any form.

There are very sophisticated versions envisioned, with possible routing capability to dynamically reroute and reconfigure communication links between tags. This will allow many tags to work together in a battlefield to provide redundant capability, and in the case of eventual loss of adjacent tags, to maintain communication. These could be placed on soldiers to provide status between units, companies, etc. They could form a Local Area Network (LAN) for logistics on the battlefield. The Internet tags would provide the capability for a fully distributed information system with a completely new paradigm. They could interact with and update existing databases through SQL.

Intelligent

These tags are based on Internet tags with the addition of expert systems capability; provide self-awareness and self-determination; they look out for themselves; will most likely require very high speed computing with very low power requirements; and expected to be available early next century.

Interrogators – Interrogators are the companions of tags. They provide the interface between humans or automated systems and tags. Most interrogators are assumed to be connected to some information infrastructure processing capability, such as C^4I^2 and LOGAIS systems. Each identified interrogator type and its fundamental characteristics follows [Ref. 17: pp. 18-20]:

LAN Interrogators

Gun

These are like barcode readers, for reading passive and package tags; directional and/or very close proximity readable; illuminate tags, possibly providing RF power to tags for activation and operation; commercially available for passive tags; and could interface with existing barcode systems.

A commander or logistician will be able to send E-mail or messages to a PEI for identification. This will provide a uniform and consistent interface between tags, information systems, and C^4I^2 systems. [Ref. 17: pp. 20-21]

Warehouse

For fixed installations, (i.e., warehouses, ships, etc.) these interrogators read inventory and ruggedized tags at distances of tens to hundreds of feet; use very low power for unlicensed operations and have omni-directional antennas with location capability based on cellular principles; can determine tag location within approximately 150 feet; an improvement to the operating system can determine tag location to within ten feet using triangulation; can be wired together in daisy-chain networks using standard telephone wire; commercially available; and cost approximately $1000 each.

Wireless

These are the same as warehouse interrogators except are designed for temporary outdoor use; have ruggedized cases and internal protected antennas; use RF links to form a communication network between other interrogators; battery operated with a solar powered recharge option; can be deployed on portable lighting poles/tripods for beach support areas and MPF off-load type operations; not commercially available; and costs should be less than $1500 with poles and solar panels.

Hand-Held

These are the same as warehouse interrogators except they are man-holdable and have a shorter range; include built-in computers, displays, and keyboards; battery operated and rechargeable; can read/write information to individual tags and transfer information to other computers; commercially available; and cost approximately $2000 each.

Direction Finding

These are the same as hand-held interrogators with the addition of direction finding and ranging capability; provide direction and distance to tags, but require tags with direction finding transponders to operate; current designs use ultrasonics; can be used in large warehouses and buildings to locate items; may be combined with a special helmet and heads-up display to "show" warehouse personnel item location; are currently in prototype stage.

Long-Range

These are the same as wireless interrogators except for reading long range tags over a higher power transmitter; have larger antennas to aid locating items on large bases; transmission ranges are thousands of feet; may be deployed statically or on vehicles to locate items; antennas may be separate from the basic unit for roof and tower mounting; not commercially available; and costs should be less than $1500 with poles and solar panels.

Battlefield Radio

These are the same as long range interrogators except for reading battlefield radio tags; may actually be a battlefield digital radio modified or adapted for reading tags and would serve multiple purposes, including communications; support spread spectrum and encryption; serve as a gateway into C^4I^2 systems; not commercially available; and may be quite expensive, depending upon basic military radio costs.

Wide Area Network (WAN) Interrogators

Flying

These would be special interrogators mounted on an airplane, balloons, or Remotely Piloted Vehicles (RPV); and could conceivably monitor entire battlefields.

Satellite

These interrogators could be hosted on geosynchronous or LEO satellite; geosynchronous would provide constant coverage at the expense of higher tag transmitted power and/or more complex antennas, thus higher costs; LEO satellites would be much closer to earth, thus requiring much lower power and possibly simpler antennas; primary disadvantage is limited time and view, and a larger number of satellites would be required for continuous coverage (if delayed information retrieval in hours is allowed, then fewer satellites would be required, at much lower costs).

Internet/C^4I^2 Interrogators

Internet

The first realization of an Internet tag will probably be an Internet interrogator because of the amount of computer processing and memory required; will hold, recognize, and route information without transmission to ground stations; in the case of flying and satellite interrogators, they would be "Internet nodes in the sky"; connect directly to C^4I^2 networks for transmission of logistics information; and do not presently exist.

Intelligent

As in the intelligent tags, these would require considerable computer power and memory; will coordinate and support tags up to intelligent tags; will act as a conductor and "know" many rules; initially there would most likely be one or more engineering work stations connected to an intelligent interrogator; and eventually, these interrogators could be self-contained.

APPENDIX G (MITLA/RF Survey)

MITLA/RF SURVEY

Purpose. Captains Amirante and Baker are students at the Naval Postgraduate School (Monterey, CA); they have undertaken a challenging thesis topic and request your insight, ideas and expectations about this forthcoming logistics technology. Both are logistic officers, have served as MMC's/MMO's, completed tours in various S-4/G-4 billets, and (upon graduation) will PCS to MCLB Albany to pursue this and related logistic issues.

Objective. To gather your thoughts and views regarding potential maintenance management applications for Microcircuit Technology in Logistic Applications/Radio Frequency (MITLA/RF). The MITLA/RF concept now undergoing USMC evaluation involves the use of a radio frequency transponder (RF Tag). The RF Tag is affixed to a container or PEI to receive, store, update, and transmit data concerning the location and status of the tagged item. A fixed or portable "interrogator" is the two-way link between the RF Tag and the system's software loaded on a PC. The interrogator reads data from the RF Tag and sends it to the PC, or, receives data from the PC and writes it to the RF Tag.

Background. A primary function of the MITLA/RF prototype we are now exploring will be to provide MAGTF commanders and CSS staffs the capability to generate standard and ad hoc reports that support locating, tracking, and managing assets. Ease of use by all PC skill levels, responsiveness, and the user's ability to select only the pertinent data elements needed for a specific report will be key features of the prototype. Additionally, similar systems have been successfully tested with all types of electromagnetic sensitive munitions.

Tags undergoing USMC testing come in two "flavors": (1) 2.5" x 3.5" x 2" (resembles a pager) with storage capacities of 128 bytes, 256 bytes, and 8K, and (2) 5.5" x 4.5" x 2" with capacities of 8K, 64K, and 128K (Note: a standard typed page of text is approximately 2500 bytes).

Our initial thoughts are that such systems may be useful for tracking equipment modifications, PM data, and maintenance status. This type of data storage may be particularly useful when equipment is moving through IMA, off-loading MPF ships for biennial maintenance, or when transferred between units.

MITLA/RF SURVEY

Rank/Rate: ______________________

Billet: ____

1. How satisfied are you with the present capabilities of tracking/recording USMC maintenance **in garrison** (i.e., Record Folders, PM Rosters, Mod/Cal Forms, etc.)?

1 2 3 4 5 6 7 8 9 10

Not Satisfied Extremely Satisfied

2. How satisfied are you with the present capabilities of tracking/recording USMC maintenance **when forming MAGTF's for deployment and when deployed**?

1 2 3 4 5 6 7 8 9 10

Not Satisfied Extremely Satisfied

3. The primary focus of our thesis is the application of MITLA/RF to Modification Control and PM Scheduling. Do you think these are?

a. On target, best place to start.
b. Minor issues, not worth the effort/cost.
c. Worthy causes, however, **priority** should be given to other maintenance management areas. Such as:

____

4. Please prioritize the following issues regarding MITLA/RF (1 highest – 6 lowest)

____Cost ____Workload Reduction ____System Reliability
____Training __Complexity ____Compatibility w/Other Systems

5. What alternatives to MITLA/RF do you recommend we explore to reduce/eliminate the forms/records now used to accomplish our maintenance management goals?

____

____

LIST OF REFERENCES

1. U.S. Marine Corps Order P4790.2, *MIMMS Field Procedures Manual*, Installation & Logistics Branch, HQMC, Washington, D.C., 24 June 1983.

2. U.S. Marine Corps Technical Manual TM 4700-15/1F, *Equipment Record Procedures,"* August 1988.

3. Durham, S., "MITLA — Microcircuit Technology in Logistics Applications," Presentation Handout, 1992.

4. Ames, R., *Perspectives in Radio Frequency Identification*, Van Nostrand Reinhold, New York, New York, 1990.

5. Penhan, J. R., *Logistics Applications of Automated Marking and Reading Symbols: An Overview*, Research Paper, Florida Institute of Technology, October 1982.

6. "Automatic I.D. Delivers the Data for Warehouse Efficiency," *Modern Materials Handling*, 1986.

7. Johnson, C. M., *A Proposed Model for Microcircuit Technology in Logistics Applications (MITLA) at Army Ammunition Supply Activities*, M.S. Research Paper, Florida Institute of Technology, December 1990.

8. Schuler, J. F., "Is There a New Card in Your Future?," *ID Systems*, October 1992.

9. Lesser, R., "Optical Systems Beginning to Play a Larger Role in Mass Data Storage Market," Defense Electronics, September 1993.

10. "Spectroscopy, Principles of," *Encyclopedia Britannica*, Encyclopedia Britannica Inc., Chicago, Illinois, volume XVII, 1983.

11. "Radio Frequency Identification," *Modern Materials Handling*, June 1985.

12. HQMC (I&L), Prototype Initiation Report (Draft), *Microcircuit Technologies in Logistics Applications/Radio Frequency (MITLA/RF) System Prototype*, 17 June 1993.

13. "Bionics," *Encyclopedia Britannica*, Encyclopedia Britannica Inc., Chicago, Illinois, volume II, 1983.

14. Knill, B., *New Directions in Automatic Identification – A Report on the Impact on Manufacturing and Distribution of Automatic Identification Technology*, Industry Week, Special Section, 1988.

15. Naval Civil Engineering Laboratory, *Recording and Technology*, Presentation Handout, 1993.

16. David Taylor Research Center Technical Report, *Radio Frequency Technology in Maintenance and Repair,* 31 October 1991.

17. Naval Civil Engineering Laboratory Definition Study, *Recording and Tracking Technologies (RTT) System Architecture Definition Study*, September, 1993.

18. Naval Civil Engineering Laboratory Fleet Operational Needs Statement (Draft), *Fleet Operational Need Statement for Battlefield Automated Identification Technology (BAIT)*, by S. Gunderson and K. Michon, 28 May 1993.

19. SAVI Technology Technical Brief No. 1, *Comments on Radio Frequency Selection*, 1991.

20. "Communication, Detection, and Coherent Radiation Equipment," *Commerce Business Daily*, Issue Number PSA-0601, 22 May 1992.

21. HQMC (I&L), *USMC Containerization Planning and Management Program White Paper*, 10 May 1992.

22. HQMC (I&L), *MITLA/RF Applications Evaluation Procedures Plan: Phase 1*, 1993.

23. HQMC (I&L), *ATLASS II Asset Tracking Logistics and Supply System II,* Presentation Handout, 1993.

24. Department of the Army (Combined Arms Support Command), *Improving CSS with Automatic Identification Technology (AIT) Draft*, 21 May 1993.

25. Johnson, G., "State of the Art: Not So Fast!," *Marine Corps Gazette*, July 1993.

26. Naval Civil Engineering Laboratory Technical Memorandum 60-90-02, *Required Technologies for Amphibious Logistics to Support the Over-the-Horizon Operations Concept*, by M. Murdock and D. Brown, December 1991.

BIBLIOGRAPHY

Air Force Logistics Materiel Command, *Microcircuit Technology Applications to Logistics*, April 1984.

Ames, R., *Perspectives in Radio Frequency Identification*, Van Nostrand Reinhold, New York, New York, 1990.

"Army Lost Track of Desert Storm Supplies, Theft May Have Resulted, GAO Says," *Inside the Pentagon*, October 15, 1992.

"Automatic I.D. Delivers the Data for Warehouse Efficiency," *Modern Materials Handling*, 1986.

"Bionics," *Encyclopedia Britannica*, Encyclopedia Britannica Inc., Chicago, Illinois, volume II, 1983.

Blanchard, B. S., *Logistics Engineering and Management*, Prentice-Hall, Inc., Englewood Cliffs, New Jersey, 1992.

Campo, A., "Microcircuit Technology in Logistics Technology," *Army Logistician*, September-October 1985.

Center for Naval Analysis Report (Draft), *Improving MPF Operational Effectiveness: Lessons Learned From Past Exercises and Operations*, by M. B. Geis and W. A. Wallace, 1 June 1993.

David Taylor Research Center Technical Report, *Radio Frequency Technology in Maintenance and Repair,* 31 October 1991.

Department of the Army (Combined Arms Support Command), *Improving CSS with Automatic Identification Technology (AIT) Draft*, 21 May 1993.

Drumm, W. H. and Welty, B. E., "Retailing in the Year 2000: The Quick and the Dead," *ID Systems*, September 1992.

Durham, S., "MITLA – Microcircuit Technology in Logistics Applications," Presentation Handout, 1992.

Gutierrez, D. O., *Safety Evaluations of the Microcircuit Technology in Logistics Applications (MITLA) on Electromagnetic Sensitive Munitions*, Research Paper, U.S. Army Armament Research Development and Engineering Center, Picatinny Arsenal, New Jersey, January 1991.

Hewkin, P., "Smart Tags – The Distributed Memory Revolution," *IEE Review*, June 1985.

HQMC (I&L), *ATLASS II Asset Tracking Logistics and Supply System II*, Presentation Handout, 1993.

HQMC (I&L), *MAGTF II/LOGAIS*, Instructional Pamphlet, 1991.

HQMC (I&L), *MITLA/RF Applications Evaluation Procedures Plan: Phase 1*, 1993.

HQMC (I&L), Prototype Initiation Report (Draft), *Microcircuit Technologies in Logistics Applications/Radio Frequency (MITLA/RF) System Prototype*, 17 June 1993.

HQMC (I&L), *Test and Evaluation Plan: MITLA*, 1992.

HQMC (I&L), *USMC Containerization Planning and Management Program White Paper*, 10 May 1992.

Iannnello, L., "Container Juggling," *Marine Digest and Transportation News*, July 1992.

Johnson, G., "State of the Art: Not So Fast!," *Marine Corps Gazette*, July 1993.

Johnson, C. M., *A Proposed Model for Microcircuit Technology in Logistics Applications (MITLA) at Army Ammunition Supply Activities*, M.S. Research Paper, Florida Institute of Technology, December 1990.

Knill, B., *New Directions in Automatic Identification – A Report on the Impact on Manufacturing and Distribution of Automatic Identification Technology*, Industry Week, Special Section, 1988.

Lesser, R., "Optical Systems Beginning to Play a Larger Role in Mass Data Storage Market," Defense Electronics, September 1993.

Naval Civil Engineering Laboratory Fleet Operational Needs Statement (Draft), *Fleet Operational Need Statement for Battlefield Automated Identification Technology (BAIT)*, by S. Gunderson and K. Michon, 28 May 1993.

Naval Civil Engineering Laboratory Definition Study, *Recording and Tracking Technologies (RTT) System Architecture Definition Study*, September, 1993.

Naval Civil Engineering Laboratory Handout, *Recording and Technology*, Presentation Handout, 1993.

Naval Civil Engineering Laboratory Project Management Plan, *Recording and Tracking Technologies (RTT)*, Briefing Paper, 1993.

Naval Civil Engineering Laboratory Study (Draft), *Packaging and Transportability Technologies (PTT) System Architecture Definition Study*, 29 July 1993.

Naval Civil Engineering Laboratory Technical Memorandum 60-90-01, *Capability of Combat Service Support (CSS) to Support the Over-the-Horizon Concept of Operations*, by R. A. Hamber and E. E. Lory, November 1991.

Naval Civil Engineering Laboratory Technical Memorandum 60-90-02, *Required Technologies for Amphibious Logistics to Support the Over-the-Horizon Operations Concept*, by M. Murdock and D. Brown, December 1991.

Naval Civil Engineering Laboratory Trip Report, *MITLA Program*, by S. Gunderson, 1992.

Naval Civil Engineering Laboratory Working Papers, *MITLA Concerns and Research Opportunities*, by S. Gunderson, 6 November 1992.

Penhan, J. R., *Logistics Applications of Automated Marking and Reading Symbols: An Overview*, Research Paper, Florida Institute of Technology, October 1982.

"Radio Frequency Identification," *Modern Materials Handling*, June 1985.

SAVI Technology, Inc. SBIR Phase II Proposal (Proprietary).

SAVI Technology Technical Brief No. 1, *Comments on Radio Frequency Selection*, 1991.

SAVI Technology Technical Brief No. 2, *Comments on Modulation Type*, 1991.

SAVI Technology Technical Brief No. 3, *Comments on Communication Obstruction and Reflections*, 1991.

SAVI Technology Technical Brief No. 4, *Comments on Spread Spectrum*, 1991.

SAVI Technology Technical Brief No. 5, *Comments on RF Power Safety*, 1991.

SAVI Technology Technical Brief No. 6, *Comments on Unintentional Radiation*, 1991.

SAVI Technology Technical Brief No. 7, *Comments on Minimum Power Requirement for Reliable Communication*, 1991.

Schuler, J. F., "Is There a New Card in Your Future?," *ID Systems*, October 1992.

Sheppard, J. J., "Card Technology Roundup," *ID Systems*, October 1992.

"Spectroscopy, Principles of," *Encyclopedia Britannica*, Encyclopedia Britannica Inc., Chicago, Illinois, volume XVII, 1983.

Stanford University Industrial Engineering Senior Project, *Analysis of Fixed Asset Tracking at Fast Computers*, by M. Garcia and others, April 1991.

Symbol Technologies, Inc., *Comparison of DataCode and PDF417*, 6 January 1992.

Systems and Applied Sciences Corporation, *Marking Technology Research and Asset Marking Plan*, prepared for Wright-Patterson Air Force Base, Fairborn, Ohio, August 1988.

Systems and Applied Sciences Corporation, *MITLA Commercial Applications for Marking Technologies: Research Report*, prepared for Wright-Patterson Air Force Base, Fairborn, Ohio, September 1988.

Urrows, H. and Urrows, E., "Bar Code Alternatives," *Manufacturing Systems*, September 1990.

U.S. Army Economic Analysis, *Automation Economic Analysis for the Logistics Applications of Automated Marking and Reading Symbols (LOGMARS): Required Operational Capability*, U.S. Army Logistics Center, Fort Lee, Virginia, January 1984.

U.S. Army Report, *Independent Evaluation Report for Logistics Applications of Automated Marking and Reading Symbols (LOGMARS-T) Customer Test*, U.S. Army Signal Center, Fort Gordon, Georgia, October 1969.

U.S. Army System Specification, *System Specification for Vetronics System Architecture*, U.S. Army Tank Automotive Command, Warren, Michigan, 24 April 1989.

U.S. Marine Corps Order P4790.2, *MIMMS Field Procedures Manual*, Installation & Logistics Branch, HQMC, Washington, D.C., 24 June 1983.

U.S. Marine Corps Systems Command Exploratory Development Program, *FY 1993 Block Plan for Marine Corps Landing Force Technology*, Systems Branch, Marine Corps Research, Development, and Acquisition Command, Quantico, Virginia, 24 August 1992.

U.S. Marine Corps Technical Manual TM 4700-15/1F, *Equipment Record Procedures*, Marine Corps Research, Development, and Acquistion Command, Quantico, Virginia, August 1988.

Zimmerman, J. S., "Using Smart Cards - A Smart Move," Syscon Corporation, January 1992.

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Department of Administrative Sciences
Naval Postgraduate School
Monterey, CA 93943-5002

10. LCDR Jeffrey Nevels, Code AS/NE 1
Department of Administrative Sciences
Naval Postgraduate School
Monterey, CA 93943-5002

11. Major Robert V. Amirante 2
P.O. Box 43213
Marine Corps Logistics Base
814 Radford Blvd.
Albany, GA 31704