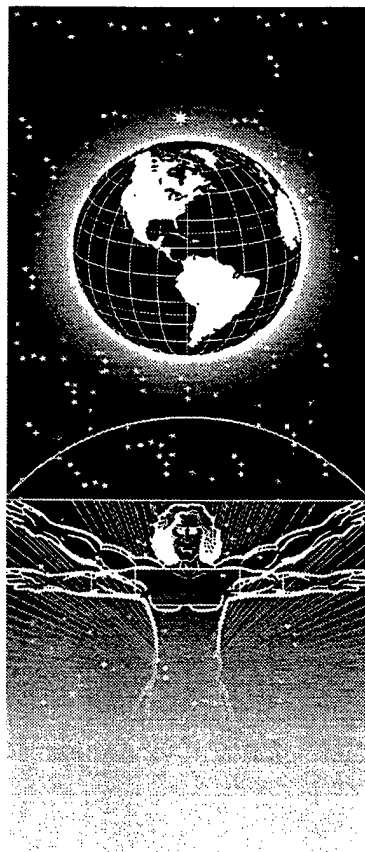




UNITED STATES AIR FORCE RESEARCH LABORATORY

Automated Identification Technology for Logistics Control (AITLC)

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January 2001

Final Report for the Period March 2000 to January 2001

20011102 062

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TECHNICAL REVIEW AND APPROVAL

AFRL-HE-WP-TR-2001-0048

This report has been reviewed by the Office of Public Affairs (PA) and is releasable to the National Technical Information Service (NTIS). At NTIS, it will be available to the general public, including foreign nations.

This technical report has been reviewed and is approved for publication.

FOR THE COMMANDER


ALBERT S. TORIGIAN, Lt Col, USAF
Deputy Chief
Deployment and Sustainment Division
Air Force Research Laboratory

REPORT DOCUMENTATION PAGE			Form Approved OMB No. 0704-0188	
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188), Washington, DC 20503.				
1. AGENCY USE ONLY (Leave blank)		2. REPORT DATE January 2001		3. REPORT TYPE AND DATES COVERED Final - March 2000 - January 2001
4. TITLE AND SUBTITLE Automated Identification Technology for Logistics Control (AITLC)			5. FUNDING NUMBERS C: F33615-99-D-6001 PE: 62202F PR: 1710 TA: D0 WU: 09	
6. AUTHOR(S) Graydon K. Hicks, Nick Patton				
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) TASC, Inc. 2555 University Blvd. Fairborn, OH 45324			8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES) Air Force Research Laboratory, Human Effectiveness Directorate Deployment and Sustainment Division Air Force Materiel Command Logistics Readiness Branch Wright-Patterson AFB, OH 45433-7604			10. SPONSORING/MONITORING AGENCY REPORT NUMBER AFRL-HE-WP-TR-2001-0048	
11. SUPPLEMENTARY NOTES AFRL Monitor: Capt. Kenneth R. Eizenga, AFRL/HESR, (937)255-3771				
12a. DISTRIBUTION AVAILABILITY STATEMENT Approved for public release; distribution is unlimited.			12b. DISTRIBUTION CODE	
13. ABSTRACT (Maximum 200 words) This task was performed under the Logistics Technology Research Support (LTRS) contract (F33615-99-D-6001) for Capt. Kenneth Eizenga of the Air Force Research Laboratory (AFRL), Logistics Readiness Branch (HESR) at Wright-Patterson AFB, OH. The research covered the time period 29 March 2000 through 31 January 2001. This effort examined the feasibility of developing a suite of passive data collection tools and corresponding transmission methods for use in logistics command and control. The tools identified can provide identification, location, and/or status information to a central control system. The effort consisted of a technology survey of available data capture and transmission equipment and methods, as well as a projection of future capability. The technologies investigated are known in the community as Automated Identification Technology (AIT). This survey evaluated key technical parameters relevant to the implementation of these technologies in an Air Force (AF) environment, including data resolution, transmission method, transmission range, storage capability, affordability, deployability, supportability, data security, and safety.				
14. SUBJECT TERMS Automated Identification Technology (AIT) Radio Frequency Identification (RFID) Smart Card Passive Sensors Active Sensors Wireless LAN Logistics Speech Technology			15. NUMBER OF PAGES 122	
			16. PRICE CODE	
17. SECURITY CLASSIFICATION OF REPORT UNCLASSIFIED	18. SECURITY CLASSIFICATION OF THIS PAGE UNCLASSIFIED	19. SECURITY CLASSIFICATION OF ABSTRACT UNCLASSIFIED	20. LIMITATION OF ABSTRACT UL	

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PREFACE

This task was performed under the Logistics Technology Research Support (LTRS) contract (F33615-99-D-6001) for Capt. Kenneth Eizenga of the Air Force Research Laboratory (AFRL), Logistics Readiness Branch (HESR) at Wright-Patterson AFB, OH. The period of research covered the time period 29 March 2000 through 31 January 2001. This effort examined the feasibility of developing a suite of passive data collection tools and corresponding transmission methods for use in logistics command and control.

EXECUTIVE SUMMARY

In logistics control centers, considerable time and effort are spent monitoring the status and location of assets such as aircraft, munitions, personnel, ground equipment, and consumables. Logistics commanders must have the most current information available to make accurate decisions about prioritization or redirection of assets. In wartime, asset status and location frequently change during the time it takes information forwarded by current methods to reach the commander.

The Air Force Research Laboratory's (AFRL) Logistics Control and Information Support (LOCIS) program is developing an architecture to improve logistics command and control operations by providing commanders rapid access to all information required to manage logistics resources effectively and meet mission objectives. To achieve maximum benefit, accurate and timely access to information on the status of various logistics resources is essential. Data collection technologies currently available and under development in the commercial sector have potential to provide the required status information on a near real-time basis.

This effort examined the feasibility of developing a suite of passive data collection tools and corresponding transmission methods for use in logistics command and control. The tools identified can provide identification, location, and/or status information to a central control system. The effort consisted of a technology survey of available data capture and transmission equipment and methods, as well as a projection of future capability. The technologies investigated are known in the community as Automated Identification Technologies (AIT). This survey evaluated key technical parameters relevant to the implementation of these technologies in an Air Force (AF) environment, including data resolution, transmission method, transmission range, storage capability, affordability, deployability, supportability, data security, and safety.

There are three tasks identified in the Statement of Work (SOW) for this contractual effort:

- Review current and evolving data collection technologies.
- Analyze the technologies and recommend possible use.
- Compare technologies to LOCIS requirements.

Absent a defined concept of operations (CONOPS), we designed a concept of exploration that identified key logistics areas. The logistics areas identified are those normally monitored by a wing logistics control agency. The primary logistics control elements identified include Aircraft Maintenance, Munitions, Transportation, Supply (Petroleum, Oil, and Lubricants [POL] only), Mobility, and Contracting. Affiliated elements were also identified: Medical, Civil Engineer, Services, and Flight Operations. Once the logistics element architecture was designed, we identified objects (things or people) that needed to be tracked. Objects that did not bear directly upon the flightline operation are identified, but we did not focus on them. Once we knew the logistics control elements and the objects to be tracked, it became an exercise to identify available AIT. At the early stage of this identification, we did not differentiate whether the technology was fully mature, in prototype stage, or only in research. Technology information was gathered from previously performed studies, commercial and government periodicals, the Internet, the U.S. Patent Office, and directly from AIT vendors. We found there are few fully passive systems available for flightline logistics control monitoring.

Only about four major technology categories bear directly upon this project: bar codes, radio frequency identification (RFID) and radio frequency data collection (RFDC), memory cards, and biometrics. Pieces of these core technologies can be combined to develop a passive logistics control

suite of AIT. In addition to the technologies we discovered and discussed, there are two main data transmission methods: hard-wired local area networks/wide area networks (LAN/WAN), and wireless. Wireless systems can be low power transceivers, satellite relayed signals, or Internet service provided by government and commercial servers. We found the data collection technologies and data transmission methods were generally accepted throughout the world, but standardization is still a problem. Many vendors still cling to proprietary methods and standards. Also, many parts of the world do not allocate the available electromagnetic spectrum equally. This latter issue complicates the data transmission requirements both at a discrete operating location or site and among countries. This is not a problem unique to development of an AIT suite and a solution is not offered by this study.

After we identified the key logistics elements, the objects to be tracked, and suitable AIT, we compared known AIT solutions to the unpublished LOCIS CONOPS given to us. Many of the identification and reporting requirements of the LOCIS CONOPS involved use of pagers, cell phones, and computers for which little in the realm of AIT was applicable. While searching for AIT, however, we did find many Internet web sites that help identify the types of products available and information on how to select the one most appropriate for a given need. This information was provided along with suggestions for appropriate AIT solutions.

TABLE OF CONTENTS

EXECUTIVE SUMMARY	iv
TABLE OF CONTENTS	vi
LIST OF APPENDIXES	vii
LIST OF FIGURES	viii
LIST OF TABLES	viii
ABBREVIATIONS	ix
1. INTRODUCTION	1
2. BACKGROUND	2
3. METHODOLOGY	3
3.1 Overview	3
3.1.1 Requirement Definition	3
3.1.2 Data Gathering	3
3.1.3 Data Assessment	3
3.2 Limitations of AI Technologies	4
4. CONCEPT OF EXPLORATION	5
4.1 Overview	5
4.2 Logistics Environment	5
4.3 Relationships of Objects and State Variables	6
4.3.1 Operational Characteristics	13
4.3.2 State Variables	14
5. DESCRIPTION OF CURRENT AND EVOLVING TECHNOLOGIES	16
5.1 Current Technologies	16
5.1.1 Linear Bar Code	16
5.1.2 Two-dimensional (2D) Stacked and Data Matrix Bar Code Symbolology	17
5.1.3 Radio Frequency Identification (RFID)	18
5.1.4 Application Service Provider (ASP)	19
5.1.5 Real Time Locating System (RTLS)	19
5.1.6 Video Monitoring	20
5.1.7 Wireless LAN/WAN	20
5.1.8 Smart Card	21
5.1.9 Optical Memory Card (OMC)	22
5.2 Evolving Technologies	23
5.2.1 Biometrics	23
5.2.2 Pennsylvania State University (PSU) Research Program	24
6. Electromagnetic (EM) Spectrum Analysis	26
6.1 General	26
6.1.1 General Communication Requirements for AIT	26
6.1.2 Operational Concerns in the Selection of Communication Modes and Frequencies	27
6.1.3 Communication Modes	28
6.2 EM Frequencies for Wireless Modes and Their Physical Transmission Effects	29
6.2.1 Very Low Frequency (VLF), 10 – 30 kHz	33
6.2.2 Low Frequency (LF), 30 – 300 kHz	33
6.2.3 Medium Frequency (MF), 0.3 – 3 MHz	33
6.2.4 High Frequency (HF), 3 – 30 MHz	33
6.2.5 Very High Frequency (VHF), 30 – 300 MHz	34
6.2.6 Ultra High Frequency (UHF), 0.3 – 3 GHz	34
6.2.7 Microwaves (μ W), 3 – 30 GHz	34
6.2.8 Millimeter Waves (MMW), 30 – 300 GHz	34
6.2.9 Optical Frequencies	36

6.2.10	Summary of Spectrum Characteristics	37
6.3	Communication Modes with Respect to Operational Criteria	39
6.3.1	Deployability	41
6.3.2	Radio Frequency Interference/Electromagnetic Compatibility (RFI/EMC)	41
6.3.3	Transmission Security	42
6.3.4	Supportability/Reliability	44
6.3.5	Safety	44
6.3.6	Conclusion	45
7.	TECHNOLOGY PARAMETER ANALYSIS	46
7.1	Parameter Description	46
7.2	Operational Characteristics	51
7.2.1	Data Storage Capacity	51
7.2.2	Transmission Range	51
7.2.3	Standard	51
7.2.4	Maturity—Technology Readiness Level (TRL)	51
7.2.5	Reliability	52
7.2.6	Security	52
7.2.7	Safety	52
7.2.8	Strengths	52
7.2.9	Weaknesses	52
7.3	State Variables	53
7.3.1	Identification	53
7.3.2	Location	53
7.4	Practicality of Application	54
7.4.1	Cost	54
7.4.2	Deployability	54
7.4.3	Supportability	55
8.	TECHNOLOGY APPLICATION TO LOCIS REQUIREMENTS	56
8.1	Overview	56
8.2	Requirements Definition	56
8.3	Recommended Solutions	58
9.	CONCLUSIONS	61
9.1	AI Technology Functions	61
9.2	Identification Technologies	61
9.3	Location Technologies	62
9.4	State Sensing and/or Recording Technologies	62
9.5	Transmission/Communication Technologies	63
9.6	Specific Architectures	63
9.7	Recommendations for Further Study	64
9.7.1	Personnel Tracking	64
9.7.2	Speech/Speaker Recognition	64
9.7.3	Optical Memory Card	64

LIST OF APPENDIXES

Appendix A, References	65
Appendix B – ISO/IEC JTC 1/SC 31 Information Technology, Automatic Identification and Data Capture Techniques — Vocabulary	72
Appendix C – LOCIS Concept of Operations (CONOPS) Version 12.0	99

LIST OF FIGURES

Figure 4.2-1, Logistics Functional Areas	6
Figure 5.1-1, Architecture of Typical Linear Bar Code	16
Figure 5.1-2, Reading a Typical Linear Bar Code	17
Figure 5.1-3, Examples of 2D Stacked Bar Codes	18
Figure 5.1-4, Examples of 2D Matrix Bar Codes	18
Figure 5.1-5, Example of Smart Card and Embedded Biometrics Data	22
Figure 6.1-1, Possible AIT Architecture Connections	26
Figure 6.2-1, Signal Attenuation	35
Figure 6.2-2, Attenuation of EM Waves by the Atmosphere	36
Figure 6.3-1, Signal Interception or Interference	43

LIST OF TABLES

Table 4.3-1, Objects, Characteristics, and Variables	7
Table 4.3-2, Object Location Categories	14
Table 6.2-1, Conventional Names for Frequency Ranges	30
Table 6.2-2, Classification of Radio Waves	32
Table 6.2-3, General Spectrum Characteristics	37
Table 6.2-4, Frequency Response to Operating Environment	39
Table 6.3-1, Classes of Communication Links	40
Table 7.1-1, Technology Parameters	47
Table 7.2-1, Technology Readiness Levels	52
Table 7.3-1, Technology Location Categories	54
Table 8.2-1, LOCIS Requirements and Candidate Solutions	56

ABBREVIATIONS

μM	Micrometer
MW or μWave	Microwave
2D	Two-dimensional
AEF	Aerospace Expeditionary Force
AF	Air Force
AFRL	Air Force Research Laboratory
AI	Automated Information
AIT	Automated Information Technology (Technologies)
ASP	Application Service Provider
ATM	Automated Teller Machine
AWM	Awaiting Maintenance
AWP	Awaiting Parts
B/W	Black and White
C2	Command and Control
Char	Character
cm	Centimeter
CONUS	Continental United States
CONOPS	Concept of Operations
DELA	Drexler European Licensees Association
dB	Decibel
dB/nm	Decibel per Nautical Mile
DO	Delivery Order
DoD	Department of Defense
DUSD(L)	Deputy Under Secretary of Defense (Logistics)
ECM	Electronic Countermeasures
EM	Electromagnetic
EMC	Electromagnetic Compatibility
EMI	Electromagnetic Interference
EMF	Electromagnetic Fields
EMP	Electromagnetic Pulse (as from nuclear detonation)
EOD	Explosive Ordnance Disposal
EW	Electronic Warfare
FDA	Food and Drug Administration
F/L	Flightline
GHz	Gigahertz
GPS	Global Positioning System
HF	High Frequency
Hz	Hertz
ID	Identification
IDT	Interdigital Transducer
IEEE	Institute of Electrical and Electronics Engineers
IFF	Identification, Friend or Foe
IR	Infrared
IRID	Infrared Identification
ISP	Internet Service Provider
IW	Information Warfare
km	Kilometer
kHz	Kilohertz
kbyte	Kilobyte
Kbps	Kilobyte per Second
LAN	Local Area Network

LAN/WAN	Local Area Network/Wide Area Network
LASER	Light Amplification by Stimulated Emission of Radiation
LF	Low Frequency
LN	Liquid Nitrogen
LOCIS	Logistics Control and Information Support
LORAN	Long Range Navigation
LOS	Line of Sight
LOX	Liquid Oxygen
LPI	Low Probability of Interception
LR	Long Range
m	Meter
MB	Megabyte
Mbyte	Megabyte
Mbps	Megabyte per Second
MC	Mission Capable
MEMS	MicroElectroMechanical Systems
MF	Medium Frequency
MHz	Megahertz
MIT	Massachusetts Institute of Technology
mm	Millimeter
MMW	Millimeter Wave
MTBF	Mean Time Between Failure
Mx	Maintenance
N/A	Not Applicable
NASA	National Aeronautics and Space Administration
NBC	Nuclear, Biological, Chemical
nm	Nautical Mile
OMC	Optical Memory Card
P _{ERROR}	Probability of Error
PC	Personal Computer
PDA	Personal Digital Assistant
POL	Petroleum, Oil, and Lubricants
PSU	Pennsylvania State University
RF	Radio Frequency
RFDC	Radio Frequency Data Collection
RFI	Radio Frequency Interference
RFID	Radio Frequency Identification
ROM	Read Only Memory
RTLS	Real Time Locating System
SAW	Surface Acoustic Wave
SOW	Statement of Work
TBD	To Be Determined
TRL	Technology Readiness Level
TRS	Technology Readiness and Sustainment
TV	Television
UHF	Ultra High Frequency
UPC	Uniform Product Code
U.S.	United States
UTC	Unit Type Code
VHF	Very High Frequency
VLF	Very Low Frequency
WAN	Wide Area Network
WOC	Wing Operations Center

1. INTRODUCTION

In logistics control centers, considerable time and effort is spent monitoring the status and location of assets such as aircraft, munitions, personnel, ground equipment, and consumables. Logistics commanders must have the most current information available to make accurate decisions about prioritization or redirection of assets. In wartime, status frequently changes in the time it takes information forwarded by current methods to reach the commander.

To eliminate the sometimes agonizingly slow collection and reporting of logistics data, the Department of Defense (DoD) began a concerted effort to take advantage of current and developing automated tools. There are many technologies being touted as "the only solution," but some analysis is required in order to separate out some of the more promising ideas for further examination. Whenever possible, the technology developed as an aid to logistics commanders should require very little or no human intervention to perform the task. Our efforts examined the feasibility of developing a suite of passive data collection tools and corresponding transmission methods for use in logistics command and control. The tools identified should provide identification, location, and/or status information to a central control system.

2. BACKGROUND

The Deputy Under Secretary of Defense (Logistics) [DUSD(L)] established the DoD Logistics Automated Identification Technologies (AIT) Task Force in January 1997 to develop a logistics AIT CONOPS. The *Logistics Automatic Identification Technology Concept of Operations* was approved in November 1997. The CONOPS provided a vision of integrating existing and new AIT to support future logistics operations and emphasized the development of a suite of interoperable AIT media and infrastructure to support asset visibility and logistics operations.

The DoD AIT Task Force produced an implementation plan in March 2000, *Department of Defense Implementation Plan for Logistics Automatic Identification Technology*. This plan is a living document, providing guidance and direction for implementing AIT in DoD logistics operations. The implementation plan directs the application of AIT devices to support business processes as well as the AIT requirements of all users in the DoD logistics chain. Although the CONOPS and implementation plan are written specifically to address asset shipment information needs at each supply and transportation node of the DoD logistics chain, the underlying guidance and direction applies equally to other logistics information requirements.

The Logistics Control and Information Support (LOCIS) program is considering using AI technology to provide current status information. An AIT architecture would improve logistics command and control (C2) operations. To achieve maximum benefit, timely access to accurate information on the status of various logistics resources is essential. The AIT architecture will provide commanders with rapid access to the information required to manage logistics resources effectively and meet mission objectives. Data collection technologies currently available and under development in the commercial sector have potential to provide the required status information on a real-time basis. The research provided by this study identifies and evaluates passive and active data collection techniques for potential application to the LOCIS project and similar efforts.

3. METHODOLOGY

3.1 Overview

TASC worked with the government program manager and commercial contractors to identify, collect, and analyze existing and evolving data collection technologies and techniques. The approach included literature searches, Internet searches, contractor interviews, and a trade show attendance. TASC assessed the nature of LOCIS information needs, input-data information sources, display requirements, frequency of data updates, and operational scenario implications. The results of this analysis are summarized in Table 4.3-1, *Objects, Characteristics, and Variables* (see page 7). The table identifies and tabulates types of information required, methods of gathering the information, logical transmission techniques, resolution assessment, supportability, security, and safety.

3.1.1 Requirement Definition

To limit the scope of this investigation, a concept of exploration was developed (refer to section 4). Our concept is based upon a notional unit's need to quickly generate an aircraft force package and prepare it and the supporting people, vehicles, and equipment for deployment on short notice. Brainstorming was used to build a list of candidate objects for which location and status must be tracked by decision-makers. Each of the objects was reviewed to determine what information would be needed, how current the information should be, and how precise the location need be.

3.1.2 Data Gathering

Information was obtained from government, educational, and commercial Internet web sites as well as printed material (see Appendix A, References). Additionally, TASC attended the Frontline Solutions Expo 2000 convention, 3-5 October 2000, to discuss products currently available or in development by over 300 firms.

3.1.3 Data Assessment

The assessment was a three-phase process. First, a list of candidate objects for location/status tracking was developed and variable state data requirements were determined (refer to section 4). Second, a list of candidate technologies and their technical characteristics was developed and analyzed (refer to sections 5, 6, and 7). Third, the candidate object requirements were compared with the technologies available to perform the location/status tracking tasks and a best-fit recommendation selected for each of the candidate objects (refer to sections 4 and 8). This assessment considers the maturity of the technology, applicability to LOCIS, operational constraints, implementation schedule assessment, and a rough order of magnitude cost to implement (when known). Included within this analysis is an assessment of known limitations relating to specific technologies or communications techniques. Limitations are addressed by category (cost, schedule, safety, and performance) and magnitude of the limitations (high, medium, or low).

3.2 Limitations of AI Technologies

A major limitation for many of the technologies currently available is that a large monetary investment is required to have a robust system. Additionally, some of the tracking systems require a rather large amount of ancillary equipment (antennas, cables, cell controllers, etc.), which negatively affects units required to deploy to a site that does not have these systems installed. Finally, the providers of real time locating system (RTLS) support are reluctant to allow the customer to possess the application software and servers used to provide worldwide tracking via Internet/landline connections.

4. CONCEPT OF EXPLORATION

4.1 Overview

To secure a starting point, we first listed those items that are tracked by a logistics control or monitoring center during a requirement to generate and mobilize an aircraft, support equipment, and personnel force package. We placed no up-front limitations on the nomination of types, relative importance, or expected numbers of objects. As the list developed, we categorized the objects by type of information needed, frequency of information update needed, whether the objects are transportable (towed or under their own power), whether internal power is available or not, etc. As the matrix of objects and needs took shape, we began searching for solutions to the location and status reporting requirements. Some objects or reporting requirements assumed a larger importance than others did; some appeared to require prohibitively expensive solutions; and some appeared to have no readily available solution. Following discussions with the customer, we agreed to include all items and indicate those that did not have solutions.

Sensing technologies may, in principle, be appropriate for any operational object. Determination of that appropriateness depends upon the operational need for information about the object, as well as the operational capabilities of the given technology. For a technology to be appropriate for use with a given class of objects, the technology must be capable of providing at least the minimum required information reliably, safely, securely, and economically. (Note: A technology having greater than the minimum required capability might well be applicable to a class of objects while not being economical.) For this reason, parameters fundamental to these aspects of the performance of both objects and technologies are relevant to the consideration. The natural source for information concerning the objects of interest is a concept of operations. In the absence of an approved concept document, it has been necessary for the study team to construct a notional concept of exploration. Although this notional concept of exploration received no official validation, it compared informally with available LOCIS documentation and found to have captured the essential points of it. Information on the available technologies has been collected as part of the present survey.

4.2 Logistics Environment

AF Logistics operations involve six classic areas: Aircraft Maintenance, Munitions, Supply (POL storage and delivery only), Mobility, Transportation, and Contracting. In addition, there are other functional areas frequently monitored within logistics control centers. These affiliated areas include civil engineering, fire and crash response, medical emergency response, and base services (particularly billeting and food service). Objects from these affiliated areas, which are similar or closely related to logistics items, are included in this study.

The classic and affiliated logistics areas are depicted by Figure 4.2-1, *Logistics Functional Areas* (see page 6). The classic logistics areas are pictorially shown within the large circle. Two-headed arrows reflect the need for communication between logistics functions. The affiliated areas are shown in shaded ovals outside the large circle.

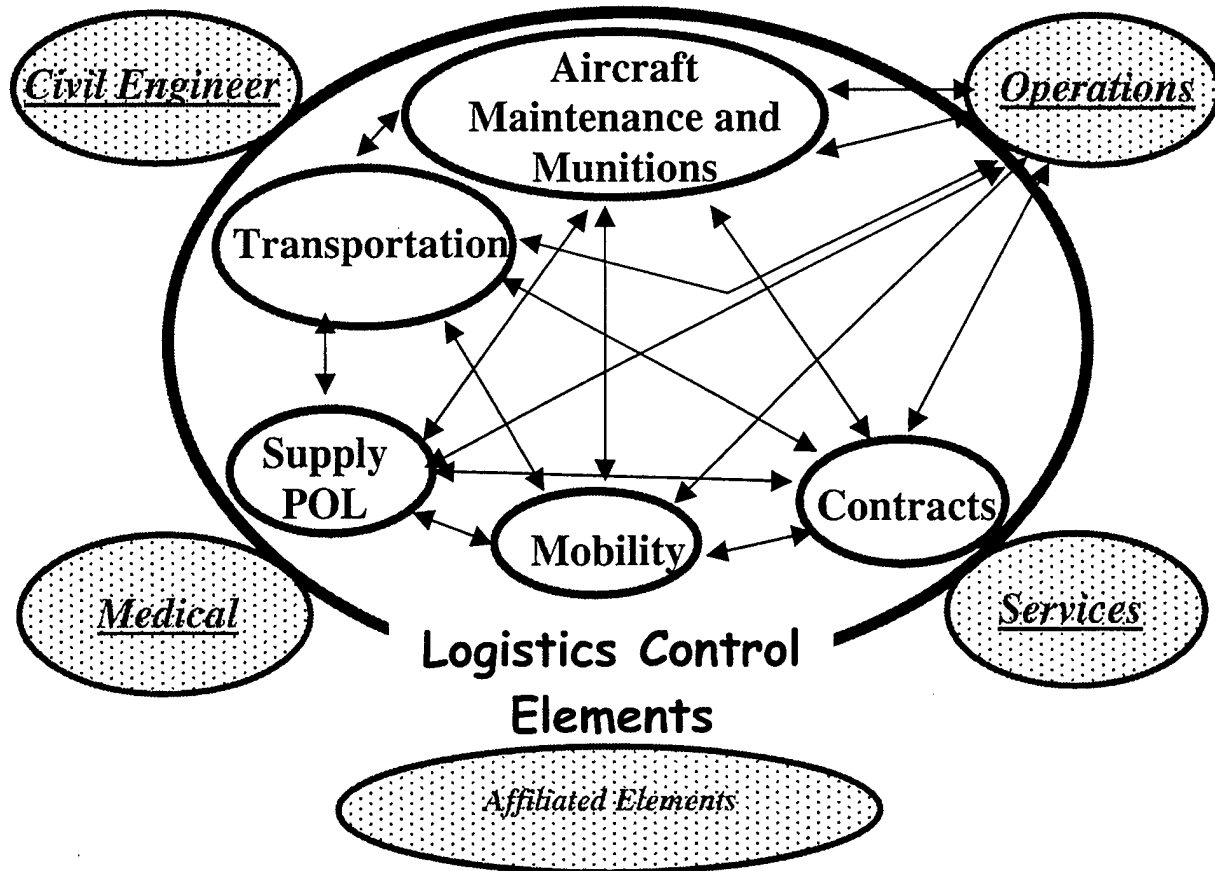


Figure 4.2-1, Logistics Functional Areas

4.3 Relationships of Objects and State Variables

Table 4.3-1, *Objects, Characteristics, and Variables* (see page 7), lists the objects we determined to be of interest to a logistics control center. Explanations of the column entries immediately follow the table in a series of notes. Some of the objects are legacy information systems that are not part of this task but were investigated in the early phases of the LOCIS project. We include some of them in Table 4.3-1 to lend weight to their importance in an overall automatic information exchange system.

Each object and technology is described in terms of its operational characteristics and a set of state variables. Three of these state variables are considered for each object and technology. They include location, identification, and condition. For objects, the performance requirement for each state variable is given. For technologies, the performance capability for each state variable is given. Not all technologies possess a capability to satisfy all the state variables. For simplicity of handling, parameters that are not naturally discrete are roughly quantified. It should also be noted that neither the choice of descriptive parameter names nor the units of measure are sacred. Their only virtue lies in the fact that they offer to open a window on the reliability, safety, security, and economy with which a technology may be applied to a class of operational objects. The descriptions that follow provide background for interpreting the tabular entries developed in the survey.

Table 4.3-1, Objects, Characteristics, and Variables

Object	Operational Characteristics				State Variables			Candidate Technologies	
	Mobility	Size	Number	Range	Electric Power	ID	Location (Accuracy & Size)	Condition(s)	
Aircraft	Mobile	Large	< 50	3 miles	Yes	Unique	6 (A, S)	R, M, Mx, IU	N/A
Aircraft Battle Damage Repair Trailer	Tow	F/L Tow	4	1500 ft	No	Type	2 (S)	R, IU, S	Active RFID, OMC
Aircraft Crash Recovery Cranes	Mobile	F/L Truck	1	3 miles	Yes	Unique	2 (S)	R, M, Mx, IU	Active RFID, OMC
Aircraft Emergency Response Vehicle	Mobile	F/L Truck	15	3 miles	Yes	Unique by type	4 (A, S)	R, M, Mx, IU	RTLS, Active RFID, OMC, Wireless LAN/WAN
Aircraft Equipment Tow Vehicle	Mobile	F/L Truck	20	1500 ft	Yes	Unique by type	4 (A, S)	R, M, Mx, IU	RTLS, Active RFID, OMC, Wireless LAN/WAN
Aircraft Ground Power Air Conditioner	Tow	F/L Tow	50	1500 ft	Yes	Type	3 (A, S)	R, Mx, IU, S	Active RFID, OMC
Aircraft Ground Power Generator	Tow	F/L Tow	50	1500 ft	Yes	Type	4 (A, S)	R, Mx, IU, S	Active RFID, OMC
Aircraft Liquid Nitrogen (LN) Servicing Cart	Tow	F/L Tow	8	1500 ft	No	Type	5 (A, S)	R, Mx, IU, S	Active RFID, OMC
Aircraft Liquid Oxygen (LOX) Servicing Cart	Tow	F/L Tow	8	1500 ft	No	Unique by type	6 (A, S)	R, Mx, IU, S	Active RFID, OMC
Aircraft Maintenance Operations Center	Fixed	Large	1	contact	Yes	Unique	N/A	R, M	Feed via legacy information system, Wireless LAN/WAN
Aircraft Parking Spot Facility	Fixed	Large	< 75	contact	Near	Unique	N/A	R, IU	Video Monitor
Aircraft Production Supervisor	Mobile	Person	4	3 miles	Radio	Unique by type	4 (A, S)	R	Wireless LAN/WAN, smart card, PDA
Aircraft Refuel Pantograph	Fixed	Large	< 10	contact	Near	Unique	N/A	R, M, IU	OMC
Aircraft Refuel Pantographs	Tow	F/L Tow	< 10	1500 ft	Near	Unique	4 (A, S)	R, M, IU	OMC
Aircraft Status and Schedule Information	Info	Info	1	contact		Info	N/A		Feed via legacy information system, Wireless LAN/WAN
Aircraft Sortie Production Control Vehicle	Mobile	F/L Truck	4	3000 ft	Yes	Unique by type	3 (A, S)	R, M, Mx, IU	RTLS, Active RFID, OMC, Wireless LAN/WAN
Aircraft Tow Bar	Tow	F/L Tow	10	1500 ft	No	Type	3 (A, S)	R, Mx, S	RFID
Aircraft Tow Vehicle	Mobile	F/L Truck	8	1500 ft	Yes	Unique by type	3 (A, S)	R, Mx, S	RTLS, Active RFID, OMC, Wireless LAN/WAN
Area Portable Exterior Lighting Unit	Tow	F/L Tow	30	1500 ft	Yes	Type	3 (A, S)	R, Mx, IU, S	Active RFID, OMC
Civil Engineer Electric Supply Grid	Fixed	Large	1	contact	Yes	Unique	N/A	R, Mx	Feed via legacy information system, Wireless LAN/WAN
Civil Engineer Electric Supply Generator	Trans	Large	4	3 miles	Yes	Unique by type	4 (A, S)	R, Mx, IU, S	Active RFID, OMC
Civil Engineer Electric Supply Generators	Tow	F/L Tow	4	3 miles	Yes	Unique by type	4 (A, S)	R, Mx, IU, S	Active RFID, OMC
Civil Engineer Emergency Response Center	Fixed	Large	1	contact	Yes	Unique	N/A	R, M	Feed via legacy information system, Wireless LAN/WAN

Table 4.3-1, Objects, Characteristics, and Variables (continued)

Object	Operational Characteristics				State Variables				Candidate Technologies	
	Mobility	Size	Number	Range	Electric Power	ID	Location (Accuracy & Size)	Condition(s)		
Civil Engineer Fire Response Facility	Fixed	Large	1	contact	Yes	Unique	N/A	R,M	Feed via legacy information system, Wireless LAN/WAN	
Civil Engineer Fire Response Vehicle	Mobile	F/L Truck	10	3 miles	Yes	Unique by type	4 (A, S)	R,M,Mx,IU	RTLS, Active RFID, OMC, Wireless LAN/WAN, Smart card reader, OMC reader	
Civil Engineer Prime BEEF Team	Mobile	Person	2	3 miles	Radio	Unique by type	2 (S)	R	Wireless LAN/WAN, smart card, PDA	
Civil Engineer RED HORSE Team	Mobile	Person	2	3 miles	Radio	Unique by type	2 (S)	R	Wireless LAN/WAN, smart card, PDA	
Civil Engineer Runway Repair Equipment	Mobile	F/L Tow	5	3 miles	Mixed	Unique by type	2 (S)	R,Mx,IU,S	Active RFID, OMC	
Civil Engineer Runway Repair Team	Mobile	Person	2	3 miles	Radio	Unique by type	2 (S)	R	Wireless LAN/WAN, smart card, PDA	
Civil Engineer Water Supply/Treatment Facility	Fixed	Large	2	contact	Mixed	Unique	N/A	R,Mx	Feed via legacy information system, Wireless LAN/WAN	
Commanders	Mobile	Person	10	3 miles	Radio	Unique	5 (A, S)	R	Wireless LAN/WAN, smart card, PDA	
Deputy Commanders	Mobile	Person	10	3 miles	Radio	Unique	5 (A, S)	R	Wireless LAN/WAN, smart card, PDA	
Emergency Response Member	Mobile	Person	50	3 miles	Radio	Unique by type	4 (A, S)	R	Wireless LAN/WAN, smart card, PDA	
Flight Debrief Information	Info	Info	1	contact	N/A	Info	N/A		Feed via legacy information system, Wireless LAN/WAN	
Medical Blood Supply Information	Info	Info	1	contact	N/A	Info	N/A		Feed via legacy information system, Wireless LAN/WAN	
Medical Emergency Vehicle	Mobile	F/L Truck	4	3 miles	Yes	Unique by type	4 (A, S)	R,M,Mx,IU	RTLS, Active RFID, OMC, Wireless LAN/WAN, Smart card reader, OMC reader	
Medical Flight Surgeon	Mobile	Person	3	3 miles	Radio	Unique by type	2 (S)	R	Wireless LAN/WAN, smart card, PDA, Smart card reader, OMC reader	
Medical Hospital Beds Available Information	Info	Info	1	contact	N/A	Info	N/A		Feed via legacy information system, Wireless LAN/WAN	
Mobility Cargo Handling Vehicles	Mobile	F/L Truck	7	1500 ft	Yes	Unique by type	3 (A, S)	R,Mx,IU,S	RTLS, Active RFID, OMC, Wireless LAN/WAN, Bar code reader	
Mobility Cargo Processing Information	Info	Info	1	contact	N/A	Info	N/A		Feed via legacy information system, Wireless LAN/WAN	
Mobility Cargo Schedule Information	Info	Info	1	contact	N/A	Info	N/A		Feed via legacy information system, Wireless LAN/WAN	

Table 4.3-1, Objects, Characteristics, and Variables (continued)

Object	Operational Characteristics				State Variables			Candidate Technologies	
	Mobility	Size	Number	Range	Electric Power	ID	Location (Accuracy & Size)	Condition(s)	
Mobility Control Center	Fixed	Large	1	contact	Yes	Unique	N/A	R,M	Feed via legacy information system, Wireless LAN/WAN
Mobility Control Officer	Mobile	Person	2	3 miles	Radio	Type	2 (S)	R	Wireless LAN/WAN, smart card, PDA
Mobility Passenger Processing Information	Info	Info	1	contact	N/A	Info	N/A		Feed via legacy information system, Wireless LAN/WAN
Mobility Passenger Schedule Information	Info	Info	1	contact	N/A	Info	N/A		Feed via legacy information system, Wireless LAN/WAN
Munition Explosive Ordnance Disposal (EOD)	Mobile	Person	2	3 miles	Radio	Unique	5 (A, S)	R	Wireless LAN/WAN, smart card, PDA, Smart card reader, OMC reader
Munition Load Crew	Mobile	Person	15	2 miles	Radio	Unique by type	4 (A, S)	R	Wireless LAN/WAN, smart card, PDA
Munition Load Equipment (Non-Powered)	Tow	F/L Tow	30	2 miles	No	Unique by type	4 (A, S)	R,Mx,IU,S	RFID if munitions certified, bar code if not
Munition Load Equipment (Powered)	Mobile	F/L Truck	15	1500 ft	Yes	Unique by type	4 (A, S)	R,Mx,IU,S	RFID if munitions certified, bar code if not
Munition Sortie Frag Information	Info	Info	1	contact	N/A	Info	N/A		Feed via legacy information system, Wireless LAN/WAN
Munition Storage Igloo	Fixed	Large	10	contact	Yes	Unique	N/A	R,IU	Video Monitor, OMC reader, Smart card reader, and Bar code reader
Munition Storage Open Pad	Fixed	Large	5	contact	Mixed	Unique	N/A	R,IU	Video Monitor
Munition Tow Vehicle	Mobile	F/L Truck	10	2 miles	Yes	Unique by type	4 (A, S)	R,M,Mx,IU	RTLS, Active RFID, OMC, Wireless LAN/WAN if munitions certified
NBC Protective Equipment Information	Info	Info	1	contact	N/A	Info	N/A		Feed via legacy information system, Wireless LAN/WAN
POL Defuel Vehicles	Mobile	F/L Truck	2	2 miles	Yes	Unique by type	4 (A, S)	R,M,Mx,IU	RTLS, Active RFID, Wireless LAN/WAN, OMC
POL Fuel Storage Bladders	Fixed	Medium	3	contact	Near	Unique by type	N/A	R,Mx,IU	OMC
POL Fuel Storage Movable Tank	Fixed	Medium	4	contact	Near	Unique by type	N/A	R,Mx,IU	OMC
POL Fuel Storage Tank	Fixed	Medium	6	contact	Near	Unique by type	N/A	R,Mx,IU	OMC
POL Fuel Transmission Lines	Fixed	Large	2	contact	Near	Unique	N/A	R,Mx,IU	N/A
POL Liquid Nitrogen (LN) Production Facility	Fixed	Medium	1	contact	Yes	Unique	N/A	R,Mx,IU	Feed via legacy information system, Wireless LAN/WAN, Active RFID

Table 4.3-1, Objects, Characteristics, and Variables (continued)

Object	Operational Characteristics				State Variables			Candidate Technologies	
	Mobility	Size	Number	Range	Electric Power	ID	Location (Accuracy & Size)	Condition(s)	
POL Liquid Nitrogen (LN) Storage Tank	Fixed	Medium	1	contact	Near	Unique	N/A	R,Mx,IU	Feed via legacy information system, Wireless LAN/WAN, Active RFID
POL Liquid Oxygen (LOX) Production Facility	Fixed	Medium	1	contact	Yes	Unique	N/A	R,Mx,IU	Feed via legacy information system, Wireless LAN/WAN, Active RFID
POL Liquid Oxygen (LOX) Storage Tank	Fixed	Medium	1	contact	Near	Unique	N/A	R,Mx,IU	Feed via legacy information system, Wireless LAN/WAN, Active RFID
POL Refuel Vehicle	Mobile	F/L Truck	8	2 miles	Yes	Unique by type	4 (A, S)	R,M,Mx,IU	RTLS, Active RFID, Wireless LAN/WAN, OMC
Security Response Member	Mobile	Person	30	3 miles	Radio	Unique by type	5 (A, S)	R	Wireless LAN/WAN, smart card, PDA
Security Response Vehicle	Mobile	F/L Truck	10	3 miles	Yes	Unique by type	5 (A, S)	R,M,Mx,IU	RTLS, Active RFID, Wireless LAN/WAN, OMC
Security Entry Control Point	Fixed	Medium	12	contact	Mixed	Unique by type	N/A	R,M	Video Monitor, Smart card reader, OMC reader
Services Aircrew Quarters	Fixed	Large	2	contact	Yes	Unique by type	N/A	R	Feed via legacy information system, Wireless LAN/WAN
Services Bed Capacity Information	Info	Info	1	contact	N/A	Info	N/A		Feed via legacy information system, Wireless LAN/WAN
Services Food Prep Capacity Information	Info	Info	1	contact	N/A	Info	N/A		Feed via legacy information system, Wireless LAN/WAN
Services Food Storage	Fixed	Large	2	contact	Yes	Unique by type	N/A	R	Feed via legacy information system, Wireless LAN/WAN
Services Tentage Information	Info	Info	1	contact	N/A	Info	N/A		Feed via legacy information system, Wireless LAN/WAN
Supply Control Center	Fixed	Large	1	contact	Yes	Unique	N/A	R,M	Feed via legacy information system, Wireless LAN/WAN
Transportation Bus (People Mover)	Mobile	F/L Truck	10	3 miles	Yes	Unique by type	4 (A, S)	R,M,Mx,IU	RTLS, Active RFID, Wireless LAN/WAN, OMC, Smart card reader
Transportation Heavy Lift/Tow Vehicle	Mobile	F/L Truck	3	3 miles	Yes	Unique by type	2 (S)	R,M,Mx,IU	RTLS, Active RFID, Wireless LAN/WAN, OMC, OMC Read/Write
Transportation Vehicle Dispatch Center	Fixed	Large	1	contact	Yes	Unique	N/A	R,M	Feed via legacy information system, Wireless LAN/WAN

Table 4.3-1, Objects, Characteristics, and Variables (continued)

Object	Operational Characteristics				State Variables			Candidate Technologies	
	Mobility	Size	Number	Range	Electric Power	ID	Location (Accuracy & Size)	Condition(s)	
Transportation Vehicle Repair Facility	Fixed	Large	1	contact	Yes	Unique	N/A	R,M	Feed via legacy information system, Wireless LAN/WAN, OMC Read/Write
Wing Command Center	Fixed	Large	1	contact	Yes	Unique	N/A	R	Feed via legacy information system, Wireless LAN/WAN
Wing Mobile Command Center (vehicle)	Fixed	F/L Truck	1	3 miles	Yes	Unique	N/A	R,Mx,IU,S	RTLS, Active RFID, Wireless LAN/WAN, OMC

Table 4.3-1 Explanations

Operational Characteristics

Mobility: (Normal state when in operation)
 Not normally moved (Fixed): (such as a building)
 Transportable (Trans): move on trailer, forklift, etc.
 Towable (Tow): move by towing
 Mobile (Mobile): move under own power
 Info (Info): feed from legacy information system

Size: (What kind of monitoring system is feasible?)
 Flightline Truck (F/L Truck)
 Towable Flightline Units (F/L Tow)
 Person (Person)
 Large (Large): big, complex
 Medium (Medium): big but not complex
 Info (Info): feed from legacy information system

Number: (approximation)
 10, 100, 1000

Range: (Radius of normal operation of the object)
 Contact (touching or nearly touching the object)
 A distance of about 10, 100, 1000 feet, or a number of miles

State Variables

ID: Unique: only ID of its kind/type (i.e., F-15E, serial number 85-0345)
 Type: several of same type - totally interchangeable
 Unique by Type: several of same type; must track each unique object
 Info: information feed from legacy information system

Location: 1 (S) Object is "inside"/"not inside" of the largest (Size) local controlled-access area (e.g., air base)
 2 (S) Object is "inside"/"not inside" of one or more relatively small (Size) controlled-access areas (e.g., motor pool) either inside or outside the largest local area
 3 (A, S) Object is in a specific location (Accuracy) within a small (Size) controlled-access area (e.g., where in the motor pool is a given vehicle?)
 4 (A, S) Object is in a specific location (Accuracy) within the largest (Size) controlled-access area (e.g., where in the air base is a given vehicle?)
 5 (A, S) Object is in a specific location (Accuracy) within an area (Size) surrounding the largest controlled-access area (e.g., where in the community containing the air base is a given vehicle?)
 6 (A, S) Object is in a specific location (Accuracy) within a very large (Size) area, perhaps worldwide

Condition: Ready (R)
 Manned (M)
 Maintenance (Mx)
 In Use (IU)
 Storage (S)

4.3.1 Operational Characteristics

In this area, we describe the nature of the object and its use in wing operations.

- **Mobility:** The mobility of an object identifies whether it moves, and if it does, whether it moves under its own power. That is, what is the normal state when in operation? Mobility tells us whether an object must have some location tracking associated with it. A building object may be entered into a database only once but a fuel truck needs to be tracked on a continuous or periodic basis. In this study, mobility categories are:

- ◆ **Fixed (Fixed):** a facility or an equipment item that is not normally moved;
- ◆ **Transportable (Trans):** can be moved on a trailer, forklift, etc;
- ◆ **Towable (Tow):** can be moved by towing on its own wheels;
- ◆ **Mobile (Mobile):** can move under its own power; and,
- ◆ **Info (Info):** feed from a legacy information system.

- **Size:** The size of an object simply limits the size of sensing technology that may be applied to it. It provides a criterion for rejecting classes of technology that are too large to fit the object needing to be tracked. The size categories used in this study are:

- ◆ **Flightline Truck (F/L Truck):** a truck, car, or similar sized self-propelled motor vehicle;
- ◆ **Towable Flightline Unit (F/L Tow):** portable light units, power units, etc;
- ◆ **Person (Person):** a human;
- ◆ **Large (Large):** large, complex object, e.g., a fixed aircraft refuel pantograph;
- ◆ **Medium (Medium):** large but not complex, e.g., a fuel storage bladder; and,
- ◆ **Info (Info):** feed from a legacy information system.

- **Number:** The number (quantity) of objects in a type is important for cost estimation. For a one-of-a-kind object, an elaborate, costly sensing system may be feasible. For an object that is present in large numbers, the cost per object must be kept under control. Number categories are estimated as order of magnitude only, e.g., 1, 10, 100, etc.

- **Range:** By range we mean the radius of normal operation of the object. That is, over what sort of area does the object have to be tracked and identified? Again, orders of magnitude are used for these categories. Mixed units are used because several technologies have ranges of a few inches or feet while others operate at much greater distances. The following categories span two operational ranges:

- ◆ **Contact (touching or nearly touching), and**
- ◆ **A number of feet or miles of movement.**

- **Electric Power:** This parameter is not simply a yes or no. It indicates whether an object has access to electric power. The implication is that if it does, then the sensing system employed with it need not have its own power supply but can use that of the object. This avoids the weaknesses or limitations associated with the use of batteries for sensor power. The parameters are:

- ◆ **Yes:** the object has internal power, either engine- or grid-supplied;
- ◆ **No:** the object has no power available;

- ◆ Near: the object is located close to an available power source;
- ◆ Radio: the object does not have power per se but has a radio that might be used or adapted by some technology; or,
- ◆ Mixed: more than one source of power is available.

4.3.2 State Variables

Where the operational characteristics of the objects listed above are necessary for feasibility assessment, they do not address the purpose of having the sensors at all; the state variables do this. One or more technologies identify or locate the objects, sense the condition (if appropriate), and report the information automatically.

- ID: This descriptor identifies if the object is unique worldwide, unique by type, or interchangeable. Here we are concerned with the amount of information required to identify the given object. Some objects, e.g., aircraft with global range, must be identified uniquely, while completely interchangeable parts need carry only their part number. We identified four categories of uniqueness as follows:

- ◆ Unique: only ID of its kind/type (e.g., F-15E, serial number 85-0345);
- ◆ Type: several of same type - totally interchangeable (e.g., 20-ton axle jack);
- ◆ Unique by Type: several of same type; must track each unique object, e.g., liquid oxygen (LOX) or liquid nitrogen (LN) servicing trailers; and,
- ◆ Info: information feed from a legacy system.

- Location: What is required in the way of location information? How precisely must the location of the object be known? This parameter has a counter-intuitive aspect arising from the broad mix of technologies that have been lumped together under the AIT umbrella. Some items require only estimates of operational area size while others require estimates of accuracy of location and area size. Table 4.3-2, *Object Location Categories*, defines the location categories used.

Table 4.3-2, Object Location Categories

Category	Definition
1 (S)	Object is "inside"/"not inside" the largest (size) local controlled-access area (e.g., air base)
2 (S)	Object is "inside"/"not inside" one or more relatively small (size) controlled-access areas (e.g., motor pool, or warehouse) either inside or outside the largest local area
3 (A, S)	Object is in a specific location (accuracy) within a small (size) controlled-access area
4 (A, S)	Object is in a specific location (accuracy) within the largest (size) controlled-access area
5 (A, S)	Object is in a specific location (accuracy) within an area (size) surrounding the largest controlled-access area
6 (A, S)	Object is in a specific location (accuracy) within a very large (size) area – worldwide

- Conditions: The following condition categories are for the most part, self-explanatory and reflect what condition(s) should be tracked for the specified object:

- ◆ Ready (R): the object has been placed into a ready-to-use condition;
- ◆ Manned (M): people are present to operate the object;
- ◆ Maintenance (Mx): the object is in a maintenance category;
- ◆ In Use (IU): the object is being used for its assigned purpose; and,
- ◆ Storage (S): the object is in storage.

5. DESCRIPTION OF CURRENT AND EVOLVING TECHNOLOGIES

Safety Considerations: Some items of AIT equipment are potential hazards to ordnance, hazardous materiel, and flammable vapors. Electromagnetic radiation emitted from AIT devices can cause premature actuation of sensitive, electrically initiated explosive elements associated with munitions. Therefore, all AIT devices that emit electronic magnetic radiation must be tested before being used in the vicinity of munitions, hazardous materiel, and flammable vapors unless they are certified as safe.

5.1 Current Technologies

5.1.1 Linear Bar Code

Bar codes have been used for several years. They are most familiar as the uniform product codes (UPC) used on items to speed point-of-sale transactions using scanners. Different combinations of the bars and spaces represent different characters. Refer to Figure 5.1-1, *Architecture of Typical Linear Bar Code*. Linear bar codes used by DoD logistics activities include the UPC and Code 39. In 1982, DoD selected Code 39 as the standard linear symbology. Whereas a UPC is generally designed only for each manufacturer and each product, Code 39 can be customized much more. Code 39 is a variable length, alphanumeric symbology using a set of 43 numeric, uppercase alphabetic, and special characters. The construct of bars and spaces together is called an element. The more characters needed, the longer the bar code element. There are many variations on how bar codes may be used. In general, this technology requires more human intervention than this contract desires. The technology should not be ignored however, as some uses for remotely read bar codes could be folded into a passive data collection system, transmitting the data either via radio or hard wire systems. Several exhibitors have devices that combine the use of bar code labels with radio frequency identification (RFID) capability. One of the premier companies in this area is Intermec (<http://corp.intermec.com/>), who has licensed its Intellitag® concept to other vendors for development and application resale. The Intellitag® is a chip/antenna system sandwiched into a printable, paper bar code label. This allows radio frequency (RF) and bar code interrogation of the label as well as eyeball read capability.

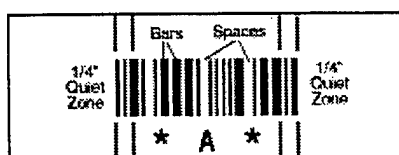


Figure 5.1-1, Architecture of Typical Linear Bar Code

When a bar code scanner is passed over the bar code, the light source from the scanner is absorbed by the dark bars and not reflected, but it is reflected by the light spaces. A photocell detector in the scanner receives the reflected light and converts the light into an electrical signal. As the wand is passed over the bar code, the scanner creates a low electrical signal for the spaces (light is reflected) and a high electrical signal for the bars (light is not reflected); the duration of the electrical signal determines wide versus narrow elements. Refer to Figure 5.1-2, *Reading a Typical Linear Bar Code*. The bar code reader decodes this signal into the characters represented by the dark bars. The decoded data is then passed to the computer in a traditional format.

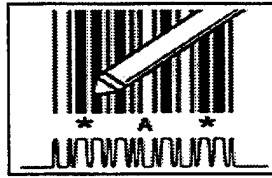


Figure 5.1-2, Reading a Typical Linear Bar Code

Benefits: Linear bar codes are low cost, easy to implement, and the technology is well known and supported throughout most industries. Linear bar codes are already frequently printed on containers or even on the objects themselves.

Limitations: Linear bar codes are frequently erroneously read when dirty, covered with snow, damaged (scratched/torn), or if the print becomes smeared due to chemical contact. The bar code cannot be rewritten to update a status. Application of one bar code label over another can be risky in that bleed through of the previous code can result in erroneous readings. Furthermore, if a second bar code tag is applied to an object without removing the previous tag, future readings may not be of the most current information.

5.1.2 Two-dimensional (2D) Stacked and Data Matrix Bar Code Symbology

2D bar codes were developed to eliminate the readability problems of damaged one-dimensional (classic) bar codes, to permit application of the symbol on very small parts, and to allow more data to be represented in a small space. There are two major categories of 2D bar codes: Stacked and Matrix. Stacked 2D bar codes are comprised of multiple bar code sequences stacked one above the other. Refer to Figure 5.1-3, *Examples of 2D Stacked Bar Codes*. Matrix 2D bar codes are arrays of regular polygon-shaped cells or dots. Refer to Figure 5.1-4, *Examples of 2D Matrix Bar Codes*. The arrangements of these shapes represent data and/or functions. Besides the obvious difference in appearance from the classic linear bar code shown in Figure 5.1-1, 2D bar codes have the ability for high data content, small size, data efficiency, and error correction capability. 2D bar codes have much the same limitations for this task as do the linear bar codes; reading the codes usually requires human intervention to get a good reading. Remote reading devices could still be used for some applications with a hard wire network relaying the information to a logistics control center, but the object being read must pass by the reader. The DoD established a standard (PDF-417) for using 2D bar codes in 1995.

Benefits: 2D bar codes are low cost, easy to implement, and the technology is well known and supported throughout most industries. Bar codes are already frequently printed on containers or even on the objects themselves. 2D bar codes employ built in data redundancy and error correction capability to reduce some of the poor read conditions of linear bar codes. 2D bar code readers can also read the older linear bar codes.

Limitations: 2D bar codes are also subject to erroneous readings when dirty, covered with snow, severely damaged (scratched/torn), or if the print becomes smeared due to chemical contact. The 2D bar code cannot be rewritten to update the status. Application of one bar code label over another can be risky in that bleed through of the previous code can result in erroneous readings. Furthermore, if a second tag is applied to an object without removing the previous tag, future readings may be made of the old tag and therefore not report current data.

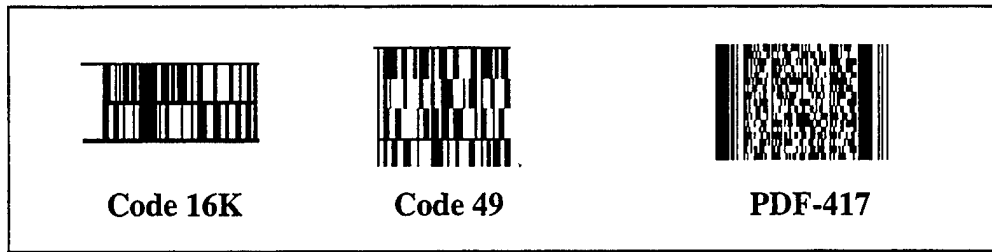


Figure 5.1-3, Examples of 2D Stacked Bar Codes

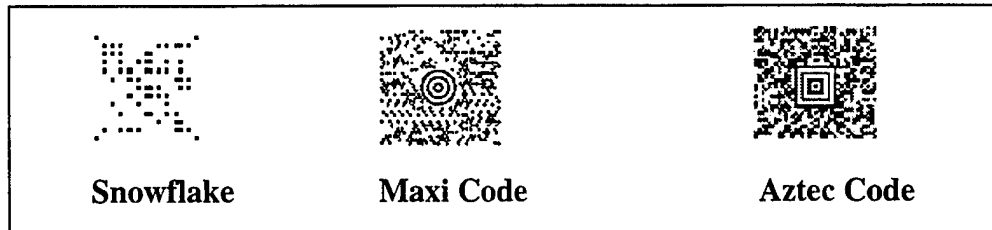


Figure 5.1-4, Examples of 2D Matrix Bar Codes

5.1.3 Radio Frequency Identification (RFID)

Both passive and active systems are becoming systems of choice. Passive and active systems differ mainly in that active tags use internal batteries to boost signal strength, thereby increasing the read range between the RFID tags and the reader/interrogator. Read range is still a problem, but vast improvements are being made. Passive systems in particular still have relatively short read ranges (about ten feet), but the technology to provide longer read ranges of up to several hundred feet using active systems is becoming more common. Some passive systems use an internal battery only to keep volatile memory functioning and not to power the data transmission. This latter use of long-life batteries doesn't solve the read range problem but does allow the devices to better link with, gather, and retain operability parameters such as pressures, temperatures, fluid levels, flow rates, etc. RFID tags fall into three broad categories.

- Inductive tags are passive. They are excited by an electromagnetic field generated by an interrogator. The tags resonate at the frequency of the field, causing a measurable disruption. These tags are useful for anti-theft, item identification, and personnel or vehicular access. They cost \$1 to \$8 per tag.
- Back Scatter tags may be either passive or active. They reflect a small portion of the interrogator's RF energy of the interrogator. The reflected signal is modulated or encoded with information stored in the tag. The tags are useful for traffic management, rail car/truck identification, and asset tracking. They cost \$5 to \$40 per tag.
- Two-Way tags are active. They incorporate a miniature transmitter and/or receiver. The tag may be polled or transmit freely. Data may be read only or programmed by the interrogator. The tags are useful for traffic management, process control, and high value control. They cost \$75 to \$200+ per tag.

Benefits: Simple RF tags are relatively cheap and have a long life. They can be incorporated with paper tags (e.g. Intellitag®) to provide visual as well as automatic tracking. Some tags can be written to electronically, providing a small database of information within the tag itself.

Limitations: The simplest read-only RF tag has a short read range – five to ten feet maximum. Achieving longer read ranges requires using an active (external power or internal battery) tag. Active tags are more expensive and have a shorter life span. While even the simple tags are cheap, the read/interrogation equipment can be expensive. Mounting RFID tags on metal surfaces has been problematic until recently, as the metal surface would attenuate the signal. Manufacturers have begun marketing tags and housings specifically engineered to mount on metal. MBBS, Ltd. (<http://www.mbbs.ch>) has developed an RFID technology and product (DistiTrace™) that reports through metal, although the technology requires near contact to perform data read or write functions. While the cost of tags is coming down (from less than \$1 to more than \$200 each), the cost of reader/interrogators is still quite high (between \$1,000 to \$12,000 each).

5.1.4 Application Service Provider (ASP)

Application Service Providers (ASPs) provide a service much like Internet Service Providers (ISPs) that individuals use for access to the Internet and for their E-mail functions. An ASP generally connects the customer's management system or cell controller server(s) to the ASP's central processor function via the Internet. The ASP's central processor then provides worldwide access to the data. Data encryption and user identification (ID) and password security controls prevent unauthorized data access and the customer's information technology overhead is not affected. The down side to this concept is that someone else has control of your data. If the Internet fails or the servers are unavailable due to failure or routine maintenance, you cannot access your data. Most ASPs use proprietary software and are not very receptive to allowing customers to host their own Internet server. This reluctance is beginning to change; some vendors indicate a willingness to at least discuss the possibility if a contract is large enough. A Gartner Group, Inc. model of ASP technology and their analysis of each level of service can be reviewed at the following web site: <http://gartner4.gartnerweb.com/public/static/hotc/hc00093846.html>.

Benefits: ASPs provide turnkey systems. They analyze the requirement, help select the correct equipment for a specific need, assist in installation, and provide round-the-clock service. The ASP normally maintains the servers at their own locations so demand on a customer's computer resources is minimized. Access to the ASP is worldwide through the Internet; data can be displayed on desktop or portable computer devices.

Limitations: An off-site ASP will be a continuous cost arrangement. Reliance on access to the data via the Internet puts the customer at risk should connectivity be degraded or lost.

5.1.5 Real Time Locating System (RTLS)

RTLS is a marriage of RFID and ASP technologies. Using either the global positioning system (GPS) or ground-based timed signal interpretation software from a grid of receivers, the location of objects or people to within ten feet can be obtained. The location of these objects is then fed to a cell controller that feeds the data to either a local server or to an ASP via the Internet. Locating and tracking the object from anywhere in the world is then just a function of connecting to the customer's ASP and using its usually proprietary software to locate the object.

Benefits: An RTLS is built to satisfy a particular customer's needs. PinPoint Corporation (<http://www.pinpointco.com/>) and RF Code, Inc. (<http://www.rfcode.com>) have formed a corporate team to field a good RTLS. Their Spider tag, a unique, active RFID tag, provides long-range or short-range identification. Tags can be identified at distances up to 300 feet from the reader with optional antennas. Spider's unique collision avoidance system provides read capability for up to 500 tags at a standard 7.5-second beacon interval and 1000 tags at a 15.4-second interval.

Limitations: Most RTLS ASPs do not relinquish their software or hardware to the customer's location or control. The impact of this is the customer is dependent upon the proper operation of the Internet infrastructure for the system to function properly.

5.1.6 Video Monitoring

Video monitoring is frequently associated with monitoring high-value asset storage areas and point-of-sales operations. It can also be a valuable means of remote, visual monitoring of general operations on an aircraft ramp, mobility in-check yard, munitions storage area, fuel storage and distribution area, etc. Used in conjunction with active/passive tracking and status reporting devices, the logistics control center could pan the camera to a point of interest and zoom in to whatever object needs an immediate visual check. With appropriate software and hardware, the video can be recorded and made available across the Internet. A good overview of using this technology can be seen at the Axxess™, Inc. web site: <http://www.axcessinc.com/>.

Benefits: Depending on system configuration, video monitoring can provide near real-time observation of key positions. It may also provide the ability to direct remote operations from wherever the video signal is being observed.

Limitations: This is not a cheap technology in terms of both dollars and valuable bandwidth. Unless an area is well lit or the video devices are built with infrared capability, operations at night or during adverse weather such as fog, heavy rain, etc., would be difficult at best.

5.1.7 Wireless LAN/WAN

A wide area network (WAN) is similar to a local area network (LAN) but of course the network distribution area is much larger for the WAN than for the LAN. A wireless system uses RF devices rather than hard wires to transmit and receive the data. A significant investment in RF equipment is required. Early use of wireless LAN/WAN solutions revolved around access to data obtained and distributed to a central server using radio signals and the typical office desktop computer. Current technologies are evolving around use of Palm, Windows CE, and EPOC driven hand-held devices as the data display product. The devices include personal digital assistants (PDAs), pocket personal computers (PCs), tablet PCs, and laptop or notebook computers. Device complexity is improving and costs are not as high as even a year ago. Yet to be fully solved is wireless LAN/WAN security. Since access devices are portals into the network and these devices are prime targets for theft, network security must receive prime attention.

The health care industry and educational institutions are adopting a wireless campus operation as a cost-effective alternative to an equipment (cabling, routers, ports, etc.) intensive, and surprisingly more expensive, traditional landline network. Integrated cell phone, bar code scanner, digital camera, and RFID reader/interrogator hand-held display devices are beginning to appear. The cost is currently quite high for these integrated devices. Industry experts, however,

expect to see both technological advances and cost decreases over the next 12 months. Some conversions to wireless are already being made as a cost savings measure in lieu of expansion of hard-wired LANs.

“The UC Davis Graduate School of Management encourages students to use wireless-enabled laptops. Six base stations located throughout the school use radio frequencies to deliver bandwidth speeds of up to 11 Mbps [megabytes per second]. The school received a \$13,000 grant to cover the costs of the wireless network, which can technically support up to 1,000 users per base station. Adding 130 wired ports, the minimum to accommodate all of the MBA students, would have cost more than \$85,000.” (From *Field Force Automation Magazine*, “Untethered Learning,” October 2000)

Benefits: Wireless LAN/WAN provides access to data at any location within range of the wireless antennas and eliminates being tethered to a desk. Even the smallest display devices are now relatively easy to use and the displays can be customized to fit individual user requirements.

Limitations: The display devices are currently fairly costly and most are not rugged. A notable exception is the newly fielded SIDEARM All-Terrain Handheld PC™ by Melard Technologies, Inc. (www.melard.com). The SIDEARM (about \$2,100) is advertised as meeting MIL-STD810E for shock, vibration, temperature, humidity, dust, etc.

5.1.8 Smart Card

Smart cards have been used for several years to provide security control and access to data terminals. Some examples are credit/debit cards, pre-paid phone cards, driver's licenses, and building entry swipe cards. These devices use either singly or in some combination magnetic stripes, bar codes, and embedded chip technologies to store data. Cards can contain a small database of their own or can be used to identify the card to a larger database within an electronically connected remote system. The Air Force recently demonstrated the successful use of smart card technology to increase the accuracy and speed of the mobility processing of personnel. Logisticians at Hurlburt Field's 16th Special Operations Wing implemented base-wide use of smart cards with a photograph, linear bar code, magnetic stripe, and an embedded 8K wafer chip. The card allows access to a large database of medical/dental, personal readiness, training, and mobility information on individual unit members. Average personnel mobility processing flow time has been reduced as much as 67 percent. One of the leading vendors of smart cards for access/security control is HID Corporation (<http://www.hidcorp.com/>). They quote embedded chip smart card prices from \$8 to \$25 depending upon the type and manufacturer of chip required, the amount/complexity of custom artwork, and which other card options are desired, such as magnetic stripes, signature panels, photographs, etc.

Benefits: One smart card can replace the functionality of several single-purpose “dumb” cards. Embedding personal identification information (e.g. digital fingerprint, photo, signature facsimile, etc.) can offer secure access to confidential information stored in remote databases. Accessing preformatted and authenticated information reduces the probability of manual transcription errors as well as greatly increasing the speed of administrative processes. In the simplest of formats, the smart card has an expected life span of years.

Limitations: Most smart cards have short read ranges (near contact up to six inches) for data transmission using a simple passive, no-battery design. The short read range drives the need for some amount of human intervention for most smart cards.

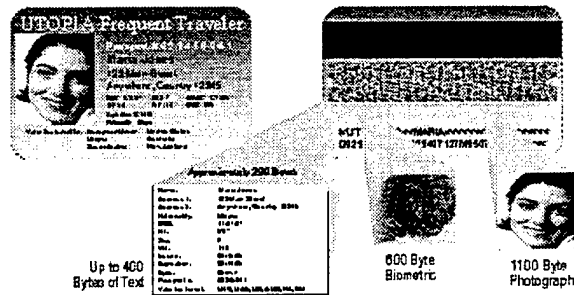


Figure 5.1-5, Example of Smart Card and Embedded Biometrics Data

5.1.9 Optical Memory Card (OMC)

An OMC is much like a smart card but uses laser energy to burn new information as needed into an optically read data layer. OMCs can be obtained with various features like the smart card to include text, bar codes, pictures, holographic photos, magnetic stripes, electronic chips, etc. The LaserCard Systems Corporation (<http://www.lasercard.com/>) offers their LaserCard® Optical Memory Card in 1.5MB and 4.1MB (2.8MB with error detection and correction) capacities. This card and cards from other vendors are written to by a high-energy laser and are read with a lower power light source. The data is non-volatile and can be updated as needed. All types of data encryption standards are supported. Independent data areas can be partitioned on the card, each of which can be accessed with separate security identification codes. Like the smart card systems, this requires human intervention to write and read the data, but the data itself could be automatically sent to any information system desired by simply programming the read device. This technology would be a good substitute for paper records maintained for much of the ground support equipment, vehicles, etc., needed by logistics. Maintenance personnel would use the OMC much like the smart cards are used to process people through a mobility line. The OMC could be read during maintenance in-check and the data updated during and upon completion of maintenance and release back into service. The DoD adopted the Drexler European Licensees Association (DELA) standard for optical memory cards.

Benefits: The optical memory cards are relatively cheap on a life-cycle basis. Manual paper record keeping would be all but eliminated. Data transfer errors when updating the record files would be eliminated. Due to the construction of the card and the memory capacity, replacements would be rare. The OMC can include security protocols to prevent unauthorized access/alteration of the data.

Limitations: As aircraft refuel data plate experience taught aircraft maintainers, equipment identification cards can become lost. This requires some backup of the data, but maintaining the backup data electronically can mitigate the impact of this. The fact that human intervention is required to use this technology fully is a minor limitation.

5.2 Evolving Technologies

5.2.1 Biometrics

Biometrics most commonly includes fingerprint, facial feature, iris scan, and voice/speaker recognition for security access controls. The Biometric Consortium (<http://www.biometrics.org/>) serves as the United States (U.S.) Government's focal point for research, development, test, evaluation, and application of biometric-based personal identification verification technology.

- **Fingerprints:** Use of fingerprints to authenticate identities has been available for a number of years. In theory, these devices, when connected to computer devices or to security control points, will positively identify and authorize or deny computer logon or area entry. They are relatively fast, accurate, and do not rely on individuals changing and remembering their User ID and Password authentication codes. As the Identix, Inc. (<http://www.identix.com/>) says "One Password for life." Devices have been developed for interface with networked systems and for standalone operation. Cost is a problem; individual input devices cost \$100 to \$400 and some require additional software costing \$70 to \$1,000.
- **Facial Features:** The Massachusetts Institute of Technology (MIT) developed an algorithm that builds a reference set of numbers that uniquely identifies each face from digitally observed/measured characteristics. The theory of facial recognition is that the set of numbers is repeatable regardless of the number of times a unique face is scanned. Like fingerprints, if the set of numbers is observed by a computerized video system, the source (a particular person) can be positively identified. The technology was first adopted for use by automated teller machines (ATM) for card authentication, and by law enforcement, casino security, and fraud agents, etc., to locate and track specific individuals within crowds. This technology could be used in conjunction with video monitoring of a ramp area to find individuals who are not in radio or RF link contact. This technology has problems notably with identical twins, admittedly not a large number, and by changes in facial appearance over time. Changes over time are also probably not a large problem for the relatively short time a person would be in a particular military data system.
- **Iris Scan:** Because error rates (albeit small) were found with overall facial scanning, technology was pushed to develop facial differentiation based upon a smaller portion of a face that would have a smaller probability of error. One of the better-documented methods is iris scanning. Iridian Technologies, Inc. (formerly known as IriScan, Inc.) is the sole owner and developer of an innovative technology called iris recognition that identifies people by the unique patterns in the iris of their eye. Iridian Technologies calculated that the probability of two irises producing exactly the same code at only 1 in 10^{78} . Iris recognition takes advantage of the mesh of tissues and resulting patterns present in all eyes. The patterns in essence become a human barcode that is usually stable throughout life. The technology developed by Iridian Technologies also filters for normal physiological response to light and natural pupillary movement that are not present in contact lenses or pictures meant to fool ordinary iris scanning instrumentation. Iris recognition technology could be quite useful for area and computer console security controls.
- **Voice Recognition and the closely related Speaker Recognition:** This technology area is being used to speed operations as well as improve efficiency by removing the need to concurrently hold a device, read a list, type a command, etc. The Air Force Command and

Control (C2) Battlelab (<http://www.c2b.hurlburt.af.mil/speechrecognition.htm>) found that when the appropriate vocabulary was used, the prototype speech recognition software recognized verbal communication 97 percent of the time. The assessment concluded that speech recognition technology was mature enough to act as a C2 computer interface. In commercial warehousing operations, product pickers use hands-free, wireless radio or telephone systems that tell them which items to pick as they move along the shelves. A properly programmed system tracks the location of the picker in relation to the warehouse shelves. The system instructs the picker which items to select in the proper order to fulfill an order. Using this technique, the product picker does not have to traverse back and forth along rows and up and down the columns of shelves/bins to get the items needed. Likewise, the system can update its database via voice command as items are received and placed on shelves or in bins. This procedure would be very useful during issue and storage of mobility bags. During issue, the system could tell the picker which bag to pull in a sequential order. Then during return to storage, the bag placer would orally update the system with the location as each bag was being stored. Other uses of speech recognition attribute voice patterns to specific individuals. Recognition and authentication of specific individuals opens the door to security controls for secure areas, computer networks, startup or shutdown of machinery, etc. The Lawrence Livermore National Laboratory has a research group devoted to speech and speaker recognition (<http://speech.llnl.gov/>). The laboratory welcomes joint collaborations in learning to use their instruments for speech and related technologies. In addition, the intellectual property associated with these concepts is available for licensing.

Benefits: Biometrics technologies are evolving to provide an almost foolproof method of individual identification. Researchers are developing tools that will reduce the rate of false rejections and false identifications to almost zero. Facial feature identification and voice/speaker recognition can be used without direct human intervention and do not require close contact with the sensing devices.

Limitations: Fingerprint and iris scan scanning and identification hardware requires close or direct contact between the person and the sensing device. Facial recognition still has some degree of difficulty differentiating between some people. Further, while technology is evolving to limit a difficulty recognizing the effects of aging on the human face, more work remains to be done.

5.2.2 Pennsylvania State University (PSU) Research Program

For the most part, the AIT tools discussed in this survey represent exploitations of conventional technologies. These are technologies that have been developed to satisfy substantial existing AIT markets. They are made of readily available items, mechanical and electronic, that are combined, synthesized, and packaged to perform various AIT tasks. The Center for the Engineering of Electronic and Acoustic Materials and Devices at The Pennsylvania State University (PSU), on the other hand, is studying the possible applications of more fundamental physical processes to satisfy the requirements of AIT. The PSU study is being done at the laboratory level so its products are not fully mature, appearing to be more of the nature of developmental models or brassboards. The products do, however, appear to be quite innovative and ultimately affordable tools for use in AIT. They may be combined in an integrated acoustic-electronic package, or used separately as components in more conventional AIT tools. The center pursues four thrust areas:

- Electromagnetic Interference (EMI), Radio Frequency Interference (RFI), Electromagnetic Pulses (EMP), and Electromagnetic Field (EMF) Shielding Materials and Coatings;

- Acoustic and Radar Materials, Coatings, Composites, and Systems;
- Smart Materials, Structures, and MicroElectroMechanical Systems (MEMS); and,
- Novel Manufacturing Techniques.

Although all of these thrust areas may at some time be applicable to AIT, the Smart Materials, Structures, and MEMS area is presently of the greatest interest. This thrust area has produced several devices that offer novel and possibly improved ways of performing the passive RFID function, and passive, remotely activated, wireless sensing. The two specific items that offer these capabilities are the fractal antenna and the interdigital transducer (IDT) based microsensor.

- **Fractal Antenna for Passive Responder:** The Fractal Antenna is a miniature antenna incorporated into an integrated circuit. It may be used separately as the antenna for a cellular telephone, or integrated into a miniature passive responder. One specific form of the Fractal Antenna described in PSU literature is a multi-band antenna for use with a multi-band cellular telephone. The applications of greatest interest for AIT are probably the ones in which the fractal antenna is integrated with an IDT microprocessor to form a passive responder for either passive identification or wireless sensing.
- **Surface Acoustic Wave (SAW) Passive Responder:** The IDT microprocessor is a special purpose device based on the flow of surface acoustic waves between inter-digitized, interlaced comb-shaped (e.g., teeth or fingers) conducting structures on a silicon chip. The Research Center has exploited the physical properties of the silicon substrate to devise wireless sensors, both remotely activated and conformal, for sensing temperature, humidity, ice, chemicals, drag, pressure, strain, deflection, shear stress, acoustic waves, and vibration.

The IDT devices have also been configured to function as a basis for object identification in much the same manner as an ordinary RFID tag. It is suggested that they may be produced in quantity at a cost per unit of about one dollar. Because these sensors have no associated power source, they depend upon the interrogation power to generate their response. Their operating range is currently about ten feet. When used in inventory control for objects passing through a choke point, they would not have the bar code limitations of requiring either restrictive orientation or a clear line of sight to the tag. All tagged objects on a pallet could conceivably be passively scanned simultaneously. Available literature does not discuss the identification capacity of the devices, but it is likely that it is comparable to a bar code.

IDT devices have also been constructed to function as accelerometers, gyroscopes, and hybrid accelerometer and gyroscope. Such devices might be used as the heart of a miniature inertial navigator, to be used as backup in the event that the Global Positioning System (GPS) capability were threatened in time of general war. It should be noted, however, that Pennsylvania State University does not appear to have pursued this path of development as yet, and the probable cost of such a capability would be prohibitive for the near future.

Another important possible application of the SAW devices is in the form of a matched filter for spread spectrum communications. Data security is an important requirement of a logistics monitoring system, and spread spectrum techniques offer one form of communication privacy. This privacy could probably be obtained economically for low power communication modes.

6. Electromagnetic (EM) Spectrum Analysis

6.1 General

The AIT survey identified a variety of components that may be assembled into AIT systems to satisfy various operational needs. Among them we found components that transmit signals for sensing purposes, and communicate sensed or recorded information to a central database. Some of the complete AI systems we found were designed to operate on an existing communication facility, such as the satellite tracking system; others left the question of infrastructure open, simply implying that one existed.

This section of the report examines possible communication structures to support data collection. It looks first at the general communication requirements for AIT systems and some practical considerations for the selection of possible communication modes and, where appropriate, the EM transmission frequencies they might employ. The discussion then turns to possible communication modalities and the physical transmission effects characteristic of the various EM frequency ranges, and finally assessments of modes and frequencies with respect to a range of operational criteria. There seems to be no reason to reject other methods of transmission, e.g., acoustic, but they do not seem to be of interest to the AIT community at this time, and will therefore not be considered here.

6.1.1 General Communication Requirements for AIT

A communication structure capable of supporting the full range of potential AI applications at wing level could be very complex. It can be viewed, however, in terms of the sub-structures that would support sensing classes of operation objects. The survey found these structures were conceptually simple. Refer to Figure 6.1-1, *Possible AIT Architecture Connections*. Sensors, as shown, either provide information to a local collection point where it is then made available to (or possibly forwarded to) a central data repository, or the sensor information is sent directly to the central data repository.

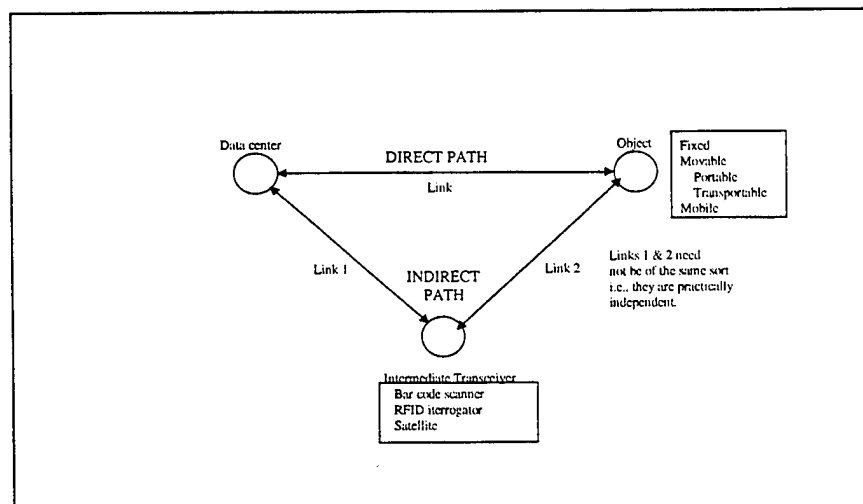


Figure 6.1-1, Possible AIT Architecture Connections

Link 2 in Figure 6.1-1 may include a sensor interrogation function or even a means of sending information to the sensor package at the object. It seems likely that most practical AIT

architectures will use the indirect path approach. The path for Link 2 in the case of most of the technologies listed in the SOW is quite short, requiring actual contact (magnetic stripe and smart cards) or very short range interrogation (bar code). The RFID technology is practically limited to ranges of about 100 feet, but in principle it could function in a direct-path architecture.

These capabilities were observed in cases of Infrared (IR) and RF identification for personnel. A hospital personnel tracking system designed by Versus Technology, for example, employs remote interrogators in all hospital areas of interest. The sensors associated with this system are ID badges worn by the personnel. The areas are pinged with an IR signal by the remote interrogators. When a badge responds to the interrogation, only the remote interrogator in the immediate area detects its response. By implication, then, the person wearing the badge is located in that area. In this case, Link 2 in Figure 6.1-1 is a local IR link involving an interrogator. Link 1, carrying the information to the data center for the hospital might be wire, radio, or optical cable. Thus, in synthesizing an AIT application, a choice is required for the nature of these links. In this instance IR was chosen for Link 2. If the context for the application had been a flightline rather than a hospital, IR might not have been the best choice. IR transmission performance is sensitive to weather conditions and might be seriously degraded in rainy weather. Each communication mode has analogous limitations. It is the purpose of this EM Spectrum Analysis to give a brief overview of these limitations and to indicate how they affect the operational concerns related to possible AIT systems.

6.1.2 Operational Concerns in the Selection of Communication Modes and Frequencies

Not only must the architecture of an AIT implementation be matched to the internal requirements of the application; the overall implementation must also be designed to cope with some higher level operational concerns. Putting together systems for use in the continental United States (CONUS) is one thing, but structuring one for use essentially anywhere in the world and under wartime conditions imposes an additional set of constraints. The implementation must be practically deployable, compatible with the deployed environment, supportable in the given environment, and safe for the people who operate it.

Deployability is concerned with how readily an AIT system based on the given technology can be deployed to a another site, probably outside of CONUS, with different local geography, weather, electromagnetic environment, information warfare threat, etc. Rapid deployability would seem to suggest wireless transmission compatible with the local electromagnetic environment, attention to security from enemy interception or manipulation, and minimal setup time for sensors. These considerations will almost certainly rule out some conceivable off-the-shelf AI technologies.

Compatibility with the local external electromagnetic environment refers to the risk of interfering with local electromagnetic systems, or of being interfered with by them. It is assumed that "interior" (i.e., interior to the deployed entity) compatibility is within the purview of our own frequency allocation control. The local allocation authority ordinarily controls exterior local emissions. Wire- or cable-based architectures are generally at low risk for incidental radio frequency interference (RFI), but wireless systems are not. The nature of the risks associated with wireless systems is discussed in the sections that follow. Dealing with them is based on exploitation of propagation and absorption phenomena for the various frequency ranges.

RFI, or electromagnetic compatibility (EMC), is concerned with incidental interaction between the AIT system(s) and the local electromagnetic environment. Though troublesome, it is

essentially benign. There is also, however, the threat of purposeful interaction by an enemy with the AIT system, i.e., electronic warfare (EW) or information warfare (IW). Assessment of the magnitude of the EW or IW threat to AIT systems is not within the scope of the present study, but a consideration of its dimensions is. There are three broad EW threats to electromagnetic information systems: interception, denial, and corruption.

- Interception involves receiving transmissions from a target system and analyzing them either for technical intelligence pertaining to the emissions themselves, or for operational intelligence based on the specific information they carry. The activity is ordinarily transparent to users of the intercepted link, and consequently has no direct effect on its operation. Intercept activity may be directed at operations using either wire/cable or wireless transmissions. The former, because the transmissions are restricted to the wires or cables, ordinarily provides greater transmission security than the latter, but even that is not absolute. Fiber optic cables probably provide the greatest transmission security against interception.
- Electromagnetic denial involves masking a target transmission with either noise or simulated signals in such a way as to reduce information flow to an essentially useless level. Denial of this sort is ordinarily directed at wireless links because wire/cable links are less susceptible to it. Wire/cable links are, on the other hand, susceptible to physical denial, i.e. simply breaking the link by somehow cutting the wire or cable, but this is usually a more difficult option to implement.
- Corruption refers to the modification of the information carried on the target link. In such an operation false information would be substituted for authentic information on the target link. This appears to be the most difficult of the IW operations to mount against an AIT system, and consequently the least likely. Wireless links would be more susceptible to such an operation, but it does not seem to be a serious threat.

Supportability of an AI technology in a deployed environment is not strongly dependent on choice of transmission frequency, but rather on the specific communication modes chosen to implement the desired architecture. A range of communication modes is discussed briefly in section 6.1.3. Wireless modes will be easier to deploy because they usually carry their infrastructure with them. Any system based on wire/cable, on the other hand, will require the installation and maintenance of a special purpose infrastructure or the use of an existing one such as a local telephone system. Wireless systems tend to avoid these additional maintenance problems and may only require repair or replacement of communication terminals.

Safety concerns the personnel using or in the vicinity of the chosen transmission technology. Like supportability, it is not strongly dependent on the choice of transmission frequency but on the combination of frequency choice and communication mode. There do not appear to be many safety issues for AIT implementations. For the most part they are accepted as safe, but some questions remain. Those that have been identified are discussed in section 6.3.5.

6.1.3 Communication Modes

What, then, are the generic modes of communication that may be employed to implement an AIT system? There appear to be two dichotomies – Wire/Wireless, and Dedicated/Existing. The first of these choices is self-explanatory. The second makes a distinction between a communication infrastructure that is implemented as part of the AIT system, and one that exists independent of

the AIT system, e.g., a local commercial structure such as the local telephone system. This method of categorization distinguishes six generic communication modes:

- Dedicated Wireless RF,
- Dedicated Wireless Optical,
- Existing Commercial Cell Phone,
- Dedicated Telephone/Data,
- Dedicated Optical Cable, and
- Existing Commercial Telephone/Data.

In principle, any one of these generic communication modes might be used in any link of an AIT architecture. In practice, however, it is unlikely that any Direct Link or Link 2 (refer to Figure 6.1-1) to a mobile object would employ a wire/cable mode. This is related to the fact that there are two aspects of transmission:

- transmission as part of the sensing activity (for example, a wireless interrogation of some device on an object), and
- transmission as conveying the sensed information to a central data facility.

Wire and/or cable connections to fixed objects would be desirable, but would not as easily support rapid setup of the system during deployment. It will be seen that both communication mode and frequency choice, in the wireless cases, bear on the degree to which a given AIT implementation satisfies the various operational criteria listed in the previous section. These modes are assessed in section 6.3 relative to the operational criteria of the preceding section.

6.2 EM Frequencies for Wireless Modes and Their Physical Transmission Effects

Choice of signal frequency for wireless transmission systems may be affected by a number of operationally significant parameters. These parameters include:

- Coverage Area (pattern control);
 - ◆ Line of Sight (obstructed areas)
 - ◆ Transmission Range (unobstructed)
- Weather Effects;
 - ◆ Transmission Range (unobstructed)
- Transmission Security;
 - ◆ Probability of Interception
 - ◆ Electronic Counter-Measures (ECM)
 - Data Denial (jamming)
 - Reduced Data Rate
 - ◆ Reduced Effective Transmission Range
 - ◆ Data Corruption (spoofing)
- Data Availability & Reliability; and,

- Radio Frequency Interference (RFI), from and with other systems.

In view of these potential impacts associated with the choice of radio frequency for wireless AIT communications, it is worthwhile to take a brief overview of the physical phenomena that distinguish the various frequency ranges. The frequency spectrum has been broken into ranges in a variety of ways and for a variety of purposes. The microwave region, for example, has been divided at different times into different sets of radar bands. In general radio engineering, however, it is more common to break up the spectrum as shown in Table 6.2-1, *Conventional Names for Frequency Ranges*. These are the names and ranges of frequency and wavelength that will be used in this discussion.

Table 6.2-1, Conventional Names for Frequency Ranges

Name	Short Title	Frequency Range	Wavelength Range
Very Low Freq.	VLF	10 – 30 kilohertz (kHz)	30 – 10 kilometer (km)
Low Frequency	LF	30 – 300 kHz	10 – 1 km
Medium Freq.	MF	0.3 – 3 megahertz (MHz)	1 – 0.1 km
High Freq.	HF	3 – 30 MHz	100 – 10 meter (m)
Very High Freq.	VHF	30 – 300 MHz	10 – 1 m
Ultra High Freq.	UHF	0.300 – 3 gigahertz (GHz)	100 – 10 centimeter (cm)
Microwaves	μWave	3 – 30 GHz	10 – 1 cm
Millimeter Waves	MMW	30 – 300 GHz	10 – 1 millimeter (mm)
Optical Frequencies		Greater than 300 GHz	Less than 1 mm

Terman (1955, p. 849) notes that "every electrical circuit carrying alternating current radiates a certain amount of electrical energy in the form of electromagnetic waves, but the amount of energy thus radiated is extremely small unless all the dimensions of the circuit approach the order of magnitude of a wavelength." For example, a power line with a 20-foot spacing between conductors carrying 60-cycle current will produce practically no radiated energy because the wavelength of a 60-Hertz (Hz) signal is more than 3000 miles, while the 20-foot spacing is negligible in comparison. A 20-foot diameter coil carrying a 2000 kilohertz (kHz) current will radiate a considerable amount of energy because 20 feet is comparable with the 150-meter wavelength of this radio wave. The point of the examples is that the size of an effective radiator is inversely proportional to the frequency it is intended to radiate. In general, therefore, smaller radiators may effectively produce higher frequency signals, but lower frequency signals require larger antenna systems for effective radiation. The required effectiveness of radiation ordinarily depends upon the range over which the signal is to be transmitted and the degree of control that is desired over the pattern of radiation. AIT applications seem to span the range of these requirements, requiring in some cases short transmission range with omni-directional coverage and in others longer ranges with controlled direction of radiation. Commercial RFID applications frequently require the former and are implemented at very low frequencies, but for some military applications examined in this survey the latter may be more appropriate.

We are concerned here with the propagation of waves in free space. These waves radiate spherically, so as they propagate, the spherical surface area they occupy increases as the square of the distance traveled. Since energy is conserved, however, the energy per unit surface area must decrease as the square of the distance. For this reason, the power of free-space waves is said to obey an inverse square law. For each doubling of the distance between the source and receiver, reduction by a factor of 4, i.e., 6-decibel (dB) loss is experienced. For all frequencies up to millimeter-wave frequencies, this spreading of the signal energy is the most important source of

loss (Bhatti, 1995). For millimeter waves and optical frequency waves there is additional loss due to atmospheric absorption that significantly limits transmission range.

Control over the noise environment is not possible when signals are transmitted through the atmosphere. Such transmissions are degraded by a number of noise sources. Natural noise, for example, is classified by its source. Atmospheric noise dominates the low frequencies, up to 2 Megahertz (MHz). It is primarily caused by electrical discharges in the atmosphere – lightning. There is also a galactic noise, i.e., radio noise originating from outside the solar system. It is important up to 200 Gigahertz (GHz). The sun itself also generates a small noise (solar noise) contribution at these frequencies. These natural sources of noise are dominated by man-made noise in urban areas. Man-made noise in the high frequency (HF) and very high frequency (VHF) bands usually consists of other signals, although the very high-power, early warning radars can generate noise in these bands. At higher frequencies, car ignition systems generate high noise levels (Bhatti, 1995). In the very low frequency (VLF) and low frequency (LF) ranges, computer monitors and television (TV) screens may generate significant interference at short ranges (Eagleson). This source of man-made noise may be particularly important for the case of an RFID system for personnel.

Table 6.2-2, Classification of Radio Waves

Class	Frequency Range	Wavelength Range	Propagation Characteristics	Typical Uses
Very Low Frequency (VLF)	10 – 30 kilohertz (kHz)	30 – 10 kilometer (km)	Low attenuation at all times of day and year; characteristics very reliable	Long-distance point-to-point communication
Low Frequency (LF)	30 – 300 kHz	10 – 1 km	Propagation at night similar to VLF but slightly less reliable; daytime absorption greater than VLF	Long-distance point-to-point service, mar-in navigational aids
Medium Frequency (MF)	0.3 – 3 megahertz (MHz)	1 – 0.1 km	Attenuation low at night and high in the daytime	Broadcasting, marine communication, harbor telephone, etc.
High Frequency (HF)	3 – 30 MHz	100 – 10 meter (m)	Transmission over considerable distance depends solely on the ionosphere and so varies greatly with time of day, season, and frequency	Moderate- and long-distance communication of all types
Very High Frequency (VHF)	30 – 300 MHz	10 – 1 m	Substantially straight-line propagation analogous to that of light waves; unaffected by the ionosphere	Short distance communication, television, frequency modulation, radar, and airplane navigation
Ultra High Frequency (UHF)	0.3 – 3 gigahertz (GHz)	100 – 10 centimeter (cm)	Same as VHF	Short-distance communication, radar relay systems, television, etc.
Microwave (μ W)	3 – 30 GHz	10 – 1 cm	Same as VHF	Radar, radio relay, navigation
Millimeter Waves (MMW)	30 – 300 GHz	10 – 1 millimeter (mm)	Same as VHF; atmospheric absorption becomes an issue; weather effects appear	Radar, low probability of interception (LPI) communications
Optical Frequencies	Greater than 300 GHz	Less than 1 mm	Same as VHF; atmospheric absorption and weather are now both important issues	Communication systems, particularly those using fiber optics, scanners for bar codes, etc.

Adapted from Terman (1955) and expanded for this presentation.

6.2.1 Very Low Frequency (VLF), 10 – 30 kHz

Propagation of VLF waves is characterized by relatively low ground-wave attenuation. The sky wave is reflected back to earth after only a very slight penetration into the ionosphere, and with little absorption (Terman 1955).

VLF systems are subject to environmental noise and are capable of handling low data rates. They produce little skip propagation by reflection from atmospheric layers and do not produce reflections from ground obstructions. Signals at these frequencies are not degraded by absorption (Eagleson).

6.2.2 Low Frequency (LF), 30 – 300 kHz

As frequency is increased above 100 kHz, the ground wave attenuates more rapidly, and the ionospheric losses grow higher in the daytime, although they remain low at night. The range of the ground wave is thus reduced as the frequency is increased, and it becomes necessary to depend upon the sky wave for communication to moderately distant points. However, because of the relatively high sky-wave absorption in the daytime, it is in general not possible to maintain dependable long-distance communication at the higher of these frequencies in the daytime, particularly in the summer, although nighttime transmission to distant points is normally possible (Terman 1955).

Like VLF transmissions, those in the LF range are subject to environmental noise and are capable of handling low data rates. Also, like the VLF, signals at these frequencies are not degraded by absorption (Eagleson).

6.2.3 Medium Frequency (MF), 0.3 – 3 MHz

In the United States, frequencies in this range are used primarily for broadcast purposes. As a consequence, operation of low-power AIT systems in this frequency range would be subject to considerable man-made noise. Since sky waves at these frequencies are completely absorbed during the daytime, broadcasting during those hours must depend entirely upon ground-wave propagation. Consequently, the daytime signal strength decreases more rapidly with distance the lower the earth's conductivity and the higher the frequency of the signal (Terman 1955).

With the higher frequency comes the potential for greater data rates. Natural noise is at a medium level, and there is little atmospheric absorption and low reflection (Eagleson).

6.2.4 High Frequency (HF), 3 – 30 MHz

The propagation of HF consists of two waves – a sky wave that bounces from the ionosphere, and a ground wave that propagates along the ground. As frequencies increase, the ground wave attenuates so rapidly that it is of no importance for anything except transmission over very short distances. As a result, practically all long-distance HF communications take place by means of ionospheric reflections (Terman 1955).

Because they have relatively long wavelengths, HF communications are not greatly affected by the troposphere. They can usually bend around even large objects such as hills. The ionosphere,

on the other hand, can support communication over great distances, but the ionosphere is not dependable and signal strengths can vary considerably (Bhatti, 1995).

Absorption and reflection at HF remain low. Skip phenomena are exploitable for long range communications, but there remains a medium noise level. Again, as the frequency increases, the potential data rate increases as well (Eagleson).

6.2.5 Very High Frequency (VHF), 30 – 300 MHz

Although the very high frequencies (VHF) are not affected by the troposphere, they are too high to exploit the ionosphere. Also, their decreased wavelength decreases their ability to diffract around obstacles (Bhatti, 1995).

Because frequencies above 30 MHz are seldom reflected back to earth by the ionosphere, the practical usefulness of frequencies above about 30 MHz therefore depends heavily upon space-wave propagation. In general, radio communication at these frequencies with reasonable power is not possible to points much beyond the line-of-sight distance. Furthermore, the elevations of the transmitting and receiving antennas are primary determinants of this distance. These frequencies are used for such applications as television and frequency modulation broadcasting; radar; aircraft-to-ground radio communication; radio navigation; radio-relay systems; and short-distance radio communications of all types, including point-to-point, moving-vehicle, walkie-talkie, etc. (Terman 1955).

6.2.6 Ultra High Frequency (UHF), 0.3 – 3 GHz

UHF transmissions have even shorter wavelengths and are still less able to diffract around obstacles than VHF. Areas in deep radio shadow can experience very poor UHF reception. In urban areas, most reception is due to scattered arrivals (Bhatti, 1995). In other respects, the UHF range is similar to VHF. UHF is also used in many of the same application areas as VHF.

6.2.7 Microwaves (μ W), 3 – 30 GHz

Microwave frequencies are usually completely blocked by obstructions. They propagate along line-of-sight geometries. Also, their wavelengths are short enough to be affected by water vapor and rain. But these effects begin to be important only above 10 GHz and are felt strongly in the millimeter wave region (Bhatti, 1995).

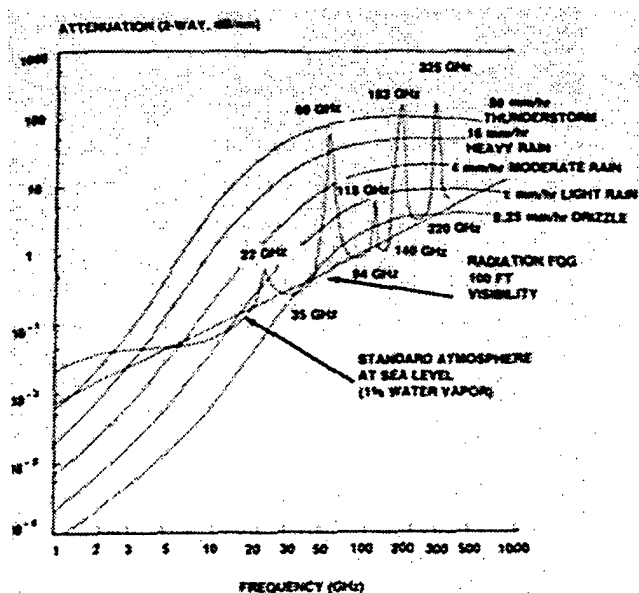
Microwaves are used in radar, radio relay, and navigation applications. They have a very high data rate potential and are confronted by negligible environmental noise. There are no skip phenomena in this region, but multipath (i.e., reflections) may complicate operations (Eagleson).

6.2.8 Millimeter Waves (MMW), 30 – 300 GHz

MMW operate in a frequency band between those occupied by microwave systems on the low side and IR systems on the other. They offer better antenna pattern control than microwave systems. They compare favorably with IR systems in their ability to penetrate dust, smoke, and certain forms of atmospheric weather conditions. Their operation, however, is generally restricted to short-range applications because MMW are subject to considerable attenuation in the lower atmosphere. Atmospheric attenuation is only half the story for waves in the MMW and

optical ranges. The other major contributor is atmospheric water (i.e., fog and rain). Schleher (1986) presents a summary figure showing the effects of both atmosphere and weather. Figure 6.2-1, *Signal Attenuation*, covers the frequency range from 1 GHz to 1000 GHz, i.e., 30 centimeters (cm) to 300 micrometers (μm .) with the MMW region running from 30 to 300 GHz. The optical region begins at that point.

Figure 6.2-1, *Signal Attenuation*, shows the approximate attenuation in decibels per nautical mile (dB/nm) for a variety of atmospheric conditions. Because the curve has been developed for use in radar analysis, the attenuation shown is two-way, twice the one-way attenuation, for the signal traverses the same path in two directions. The straight upward diagonal line beginning at about 10^{-2} dB/nm corresponds to the radiation fog condition, and the curve meandering upward and starting from just above the radiation fog line corresponds to a standard atmosphere at sea level, with one percent water vapor. The remaining smooth curves going upward to the higher frequencies correspond to several conditions of actual precipitation. Because the ordinate of the curves is logarithmic, the differences between these weather conditions may be greater than it appears at first glance. At 100 GHz, for example, the two-way attenuation in drizzle is about 4 dB/nm, while for heavy rain it is about 50 dB/nm. In the discussion that follows, the two-way values are divided by two to obtain the one-way values that are more relevant for a communication link.



Extracted from Schleher, 1986, p. 285.

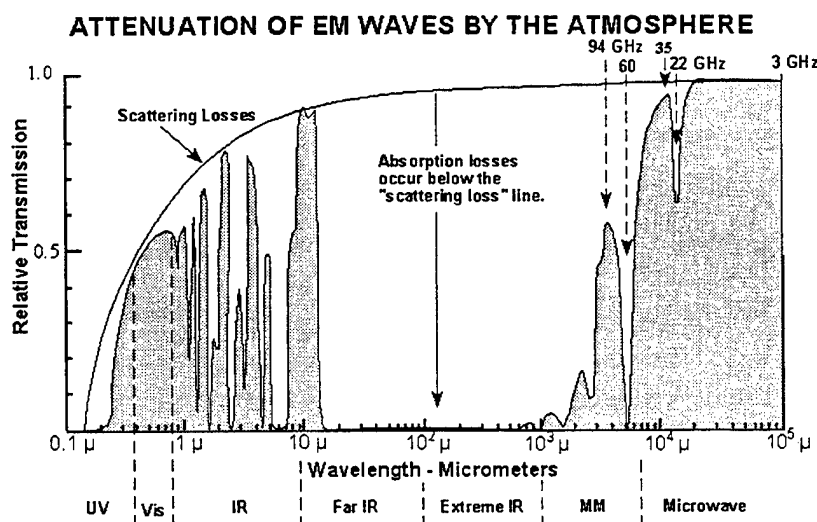
Figure 6.2-1, Signal Attenuation

The primary propagation effects at MMW frequencies are the absorption of energy by the atmosphere, scattering and absorption by rain, and absorption by fog and clouds. Absorption of MMW energy is due primarily to oxygen and water vapor. Oxygen absorption is centered around frequencies between 60 GHz (26 dB/nm, one-way) and 119 GHz (3 dB/nm, one-way). The oxygen line at 60 GHz has potential for use in low probability of interception (LPI) transmission systems. Choice of an operating frequency on the skirt of this line would limit the range at which the signal could be intercepted. Absorption by water vapor is a complicated function of water vapor content, temperature, and atmospheric pressure. There are strong water vapor absorption

lines at 22 GHz (0.4 dB/nm, one-way), 183 GHz (55 dB/nm, one-way), and 320 GHz (65 dB/nm, one-way), where the attenuation figures are for a standard atmosphere at sea level with one percent water vapor content (Schleher 1986). In the final analysis, any MMW system that operates in the atmosphere must contend with this high propagation attenuation. Unless desired for its potential security feature, this effect can only be mitigated by restricting operation to the atmospheric windows centered on 35 GHz (0.13 dB/nm, one-way), 94 GHz (0.5 dB/nm, one-way), 140 GHz (0.55 dB/nm, one-way), and 220 GHz (1.3 dB/nm, one-way) (Schleher 1986).

6.2.9 Optical Frequencies

Absorption effects affect operations for frequencies from the microwave region through the optical frequencies. Specific absorption behavior over that entire range is shown in Figure 6.2-2, *Attenuation of EM Waves*, which was extracted from the *Electronic Warfare and Radar Systems Engineering Handbook*, prepared by the Naval Air Warfare Center Weapons Division (Sticht, 2000). The figure depicts transmission through the atmosphere relative to that through free space. Although it does not give actual attenuation in dB/km, it does give a clear picture of the available transmission windows. The optical frequencies conventionally begin at 300 GHz, or $10^3 \mu\text{m}$. From that wavelength down to almost $10 \mu\text{m}$, absorption is almost total. There are scattered transmission windows in the range up to about $1 \mu\text{m}$, at which point the visible spectrum begins. The ultraviolet part of the spectrum begins at about $0.37 \mu\text{m}$.



Extracted from Sticht, 2000.

Figure 6.2-2, Attenuation of EM Waves

The interactions between radiated signals and atmospheric molecules that were seen in the microwave (μWave) and MMW ranges are much more pronounced in the optical frequencies. The transition of signals from radio to optical frequency is further marked by the manner in which circuit designs can be implemented using optical (i.e., lenses and prisms), rather than conventional electronic techniques. But the upshot of all these considerations is that atmospheric conditions play a significant role in the transmission of these frequencies through the atmosphere. This is not to say they cannot be used effectively in a fiber optic system, for example, but only that their use otherwise seems to be limited to short ranges and probably to indoor applications.

One example of such an application might be the infrared identification (IRID) and location system for hospital employees.

The IR seems to be the most useful region in the optical range. Used within the available operating windows, it is less affected by attenuating mechanism than either the visible or the ultraviolet and does not risk the kind of distraction that visible transmissions might cause. Where it is applicable, IR is reliable, secure, and relatively free from interference.

Earle (1978) lists some advantages and disadvantages of IR relative to microwaves. A paraphrased version of them follows.

- Advantages:
 - ◆ Because of their short wavelengths, superior pattern control can be obtained with infrared devices with much smaller apertures than with μ Wave and MMW devices.
 - ◆ Detection of the presence of passive infrared systems is difficult, causing increased complexity of the countermeasure problem for the enemy.
 - ◆ The energy radiated by an active IR system (e.g. communications) cannot easily be intercepted by the enemy without getting directly in the beam.
 - ◆ Circuitry in IR devices is usually simpler and cheaper than that in μ Wave and MMW devices.
- Disadvantages:
 - ◆ Clouds and water vapor greatly reduce the effectiveness of infrared systems.
 - ◆ IR sources and detectors are not as readily tunable as μ Wave and MMW devices. Hence, power may be wasted because it is of a frequency for which the detector is insensitive.
 - ◆ Passive IR systems do not give range information.
 - ◆ Background radiation, particularly in daylight, may interfere with an IR system.

6.2.10 Summary of Spectrum Characteristics

Eagleson has suggested a concise manner of summarizing important features of the various frequency ranges. His table has been expanded to cover the MMW and optical ranges. It is shown here as Table 6.2-3, *General Spectrum Characteristics*. Although it cannot show all relevant features, it does show enough to give a feel for much important behavior of the electromagnetic spectrum.

Table 6.2-3, General Spectrum Characteristics

	VLF	HF	VHF	UHF	Microwave	MMW	Optical
Data	Low	Medium	Medium	High	Very High	Very High	Very High
Noise	High	Medium	Low	Lower	Negligible	Negligible	Negligible
Skip	None	High	Troposcatter	Troposcatter	None	None	None
Absorption	Low	Low	Medium	Medium	High	Very High	Very High
Reflection	None	Low	Medium	High	High	High	High

Adapted from Eagleson (Undated), and expanded.

Eagleson also provides some examples of frequency usage for RFID systems, as well as the features of the ranges that contributed to system performance. He notes that frequencies from 50 kHz to 24.1 GHz have actually been used, and that common frequencies include:

- VLF: 50 - 150 kHz
- HF: 6.78, 13.56 MHz
- VHF: 40.68, 70-260 MHz
- UHF: 260 - 470, 902 - 928 MHz
- μ Wave: 2.4, 5.8, 10.5, 24.1 GHz

VLF and 2.4 GHz are international ranges in the sense that they have also been used for foreign RFID systems. They both possess desirable features for the application. The VLF range has high path loss and long wavelength (about 2000 meters). Hence, at practical distances the reader and tag will both always be in the near field of the other. The rapid signal falloff with distance allows tight range control but very little control of directivity. Interference from remote sources is reduced, and multipath-induced nulls due to reflection from nearby objects are negligible. The VHF, UHF, and μ Wave ranges provide a sharp contrast. For one thing, they allow for longer working distances, from 3 – 300 feet with typical ranges of 1 – 10 feet and typical long ranges of 10 – 30 feet. Also, they can support higher data rates, from one Kilobyte per second (1Kbps) to one Megabyte per second (1Mbps), with a typical rate of 10 - 250 Kbps. All of these higher frequency ranges support directional antenna patterns. They also support a broader range of modulation techniques and experience reduced noise interference compared to VLF (Eagleson).

The optical range of frequencies also offers desirable features for selected applications. For any system operating in the radio frequency ranges there is a risk of either interfering with or being interfered with by local environmental transmissions. This means that any RF AIT system requires as part of its design process a thorough study of the RF environment where it is to be implemented. Further, for a system that is intended to be deployable anywhere in the world, all possible locales must be examined. This would include at the very least a review of the government frequency allocations for each area. This step is practically unnecessary for any of the optical frequencies. They tend to be very short range and indoors because of their weather limitations, or confined to fiber optic cable. Where applicable, optical frequencies offer transmission security and reliability, with no threat of RFI.

It is worth noting that all these frequency ranges have been employed to satisfy some RFID requirement in spite of the fact that their physical characteristics are markedly different. The point is that the RFID system must be matched to the requirement it is intended to satisfy. One must not simply buy an RFID package off the shelf without a careful look at its overall operational characteristics and how well the operational need is met.

This section began with a tabulation of items of interest for any frequency. Let us close it with a summary of how potentially useful ranges measure up with respect to those items. The medium and high frequency ranges are included, although they seem to have little application. They do not offer good pattern control, and security and reliability are difficult to predict because of the strong threat of interference from environmental transmissions. The list of items includes:

- Coverage area (pattern control);
- Weather effects;
- Transmission security;
- Data availability & reliability;
- Radio Frequency Interference (RFI), from and with other systems; and,
- Electromagnetic Compatibility (EMC).

A coarse assessment of how range measures up for each of these items is shown in Table 6.2-4, *Frequency Response to Operating Environment*.

Table 6.2-4, Frequency Response to Operating Environment

Frequency Ranges	Pattern Control		Weather	Security	Reliability	RFI/EMC
	Range	Direction				
VLF and LF	Good	Weak	Good	Medium	High	Weak
MF and HF	Weak	Weak	Good	N/A	N/A	Very Weak
VHF to μ W	Weak	Good	Good	Low	High	Weak
MMW and Optical	Good	Good	Weak	High	High	Good

6.3 Communication Modes with Respect to Operational Criteria

Having examined the operational criteria, potential communication modes subject to the criteria, and propagation phenomena associated with the various radio frequencies that might be employed with the wireless modes, we now turn to an assessment of the communication modes with respect to the operational criteria. The assessment is a coarse, intuitive one, giving broad guidelines for mode selection. Mode selection would be subject to a detailed analysis before any final selection of a communication suite for a specific logistic application. It should be noted at the outset that all the systems to be discussed here are generally low-power systems. They do not, for example, include radars, but they do include laser scanners. It should also be noted that no precise quantitative assessments are made. At the present level of generality this is not feasible. The results therefore provide a guide to selection, but no more. They are summarized in Table 6.3-1, *Classes of Communication Links*. For each criterion, a brief, qualitative consideration is given each of the generic modes. In some instances the table entry is "Variable." For the most part these cells are further broken out in Table 6.2-4, *Frequency Response to Operating Environment* at the end of the preceding section.

Table 6.3-1, Classes of Communication Links

General Nature of Link	Deployability	RFI	Transmission Security			Reliability		Safety
			Intercept	Denial	Corruption	Availability	P _{Error}	
Wireless								
Dedicated RF	High	Variable ¹	Variable ¹	Variable ¹	Variable ¹	Variable ¹	Variable ¹	Variable ²
Dedicated Optical	High	None	High	High	High	Variable ⁵	Variable ⁴	Variable ²
Commercial Cell Phone	Low	Variable ³	Medium	Medium	Medium	High	Low	Variable ²
Wire/Cable								
Dedicated Telephone/Data	Med./High	None	High	High	High	High	Low	High
Dedicated Optical Cable	Medium	None	Very High	Very High	Very High	High	Very Low	Very High
Commercial Telephone/Data	Low	None	Medium	Medium	Medium	High	Low	High

¹ Variable refers to the different effects that may be expected in different parts of the frequency spectrum or when using different methods of signal modulation, for example, spread spectrum. (Refer to Table 6.2-3, *General Spectrum Characteristics*, and Table 6.2-4, *Frequency Response to Operating Environment*.)

² Variable refers to possible physical damage to the user caused by the radiation, for example, possible damage to the brain or eye of a cell phone user, or retinal damage from exposure to a modulated laser beam.

³ Variable in the case of the commercial cell phone refers to possible interference from unforeseen transmissions in a deployment area.

⁴ Variable in this instance refers to the possibility of environmental optical interference, such as sunlight, or perhaps to degraded bar codes (partially obscured by mud, for example).

⁵ Variable reliability might include obscuration (or even loss) of a bar code marker or path attenuation due to fog or rain for an IR/ID interrogator.

6.3.1 Deployability

Assessment of deployability is based on the assumption that the AIT system will deploy to a new location without an existing communication infrastructure belonging to U.S. forces. That is, although there may be existing communication, it belongs to a location that may contain hostile elements. In the view of the survey, this means the existing local communications are, at best, suspect for both transmission security and reliability. By implication, then, deployment entails establishment of a communication infrastructure completely under trustworthy control. For purposes of the survey, this has been called a dedicated structure, and within the framework of the survey it will be either a wireless system or one based on wire/cable. Systems based on local commercial communication are therefore judged to have "low" deployability even though they might be quite easy to use if available. Wireless systems, whether in RF or optical frequencies, require only terminals with no construction of physical links. They have their own operational problems (e.g., transmission security and reliability), but these are foreseeable and can be dealt with in the specific system design. Furthermore, as pointed out earlier (refer to Figure 6.1-1), all "Link 2" links to sensors associated with mobile or moveable objects demand a wireless connection. Wireless systems are therefore judged to possess "high" deployability. Dedicated systems based on wire/cable links differ from the wireless systems in that wire/cable links require construction of physical transmission links. The links must be either wire or cable to connect terminals similar to those that would be used with the wireless systems (cable as used here includes fiber optical cables). Because of this additional requirement, systems based on wire or cable links are judged to be less deployable than the wireless but more deployable than the use of existing infrastructure (i.e., "medium/high"). Similarly, installation of the fiber optics is marginally more involved than wire or cable and is therefore rated "medium."

6.3.2 Radio Frequency Interference/Electromagnetic Compatibility (RFI/EMC)

It has been assumed that interior (i.e., interior to the deployed entity) compatibility is within our own control. And it has been noted that while wire- or cable-based systems are usually free of incidental radio frequency interference (RFI), wireless systems are not. Consequently, the wire/cable systems are shown as having no ("None") RFI/EMC risks. In any event, the risk is very low. For the wireless cases, these effects are variable, depending heavily on the choice of frequency and design of the system. In the wireless, optical case there is the chance of excessive background interference from ambient light for outdoor applications in sunlight, but there appears to be only small chance of this with proper system design. The wireless cases, therefore, are shown as "Variable" (depending upon frequency), except for the optical case, which is shown as "Low."

Interference from local emitters may be avoided by, at the least, a review of official frequency allocations in the deployed area, and selection of operating frequency based upon them. But note that this suggests selection of frequencies for an RFID technology only after a deployment is decided upon. This is definitely undesirable. Ideally, of course, any system based on wireless technology would be implemented only after a local RF site survey, but this may not ordinarily be possible, or as we have seen, desirable. Choosing frequencies based on local allocations, as well as structuring the AIT system to minimize stray emission, may also control the risk of interfering with local systems. A wide range of national frequency allocation charts is available on the Web. One good example is the Superfreq.com web site (<http://www.superfreq.com/>) (Milshteyn & Staples, 2000). These charts, at best, are coarse representations of the overall allocation scheme, but they do give the broad outlines.

6.3.3 Transmission Security

The relevant components of transmission security were described in section 6.1.2. In this section, they are associated with the generic classes of communication links on the basis of a coarse, intuitive operational analysis. The purpose of the effort is to provide an indication of the considerations on which the entries in Table 6.3-1, *Classes of Communication Links*, are based. These discussions have no reference to cryptographic techniques of securing the information. That is considered to be beyond the scope of the survey. Consider first the communication links based on wire/cable.

Systems that are based on wire/cable produce minimal stray radiated electromagnetic energy. This is not to say that interception or corruption of data passing on those links is impossible, but it is not as readily affected as on the wireless systems. Dedicated, wire/cable-based links are assumed to be totally within an area controlled by trustworthy forces. Any threat to transmission security must under such a condition also seem to entail a breach of the physical security of the link. This is taken to be a difficult problem, and, hence, dedicated links based on wire/cable are considered to have at least "High" transmission security. Those based on optical cable technology present still more difficulty to information warfare intrusion, and are therefore listed as "Very High" in the matter of transmission security. The third component, denial, is similarly complicated in the case of wire/cable-based links. For the dedicated links, it practically requires physical destruction of the connecting wire/cable. The commercial wire link presents a different problem. In that case, the physical link may be accessible in areas outside friendly control. Interception by induction, without mechanical access to the wire/cable, might then be feasible, or the commercial structure itself might be under untrustworthy control. In general, the commercial telephone/data link is questionable. (Note: the author knows of no manner of accessing the data in an optical cable without mechanical access.) Its security depends upon circumstances, and for that reason is judged as "Medium" with respect to transmission security.

The wireless links present a totally different problem. With them there is necessarily radiated energy of sufficient intensity to be received at some AIT practical range. For the passive RFID application, this may be only a few feet, but for applications in which, for example, a vehicle is monitored over a large area, the ranges are significant for interception purposes. By implication, there is also the risk of denial by jamming, and depending upon the complexity of the AIT application perhaps even data corruption. These threats are naturally of greatest significance when the system is deployed to a hostile environment. Because of the variety of effects to be considered, dedicated, wireless RF links are shown as having "Variable" transmission security in the table. Guidelines for frequency selection to minimize IW threats to these links are given in Tables 6.2-3, *General Spectrum Characteristics*, and Table 6.2-4, *Frequency Response to Operating Environment*. They may all be minimized by employing Low Probability of Interception (LPI) transmission techniques, based perhaps on choice of radio frequency, antenna pattern, or modulation technique. Choice of a frequency in a range of high atmospheric absorption is an example of the first. Use of Spread Spectrum transmission is an example of the last. This latter technique would be supported, for example, by the Surface Acoustic Wave (SAW) technology applications reported by researchers at The Pennsylvania State University (see section 5.2.2 and Table 7.1-2). The SAW technology application is low-power, short-range RFID, but it could be incorporated into a longer-range communication device.

There is only so much that can be done along those lines. A simple example based on an AIT application that requires location quality of either 1 or 4 for a "mobile" object serves to indicate

the difficulty. Figure 6.3-1, *Signal Interception or Interference* shows a highly idealized geography for such an AIT application.

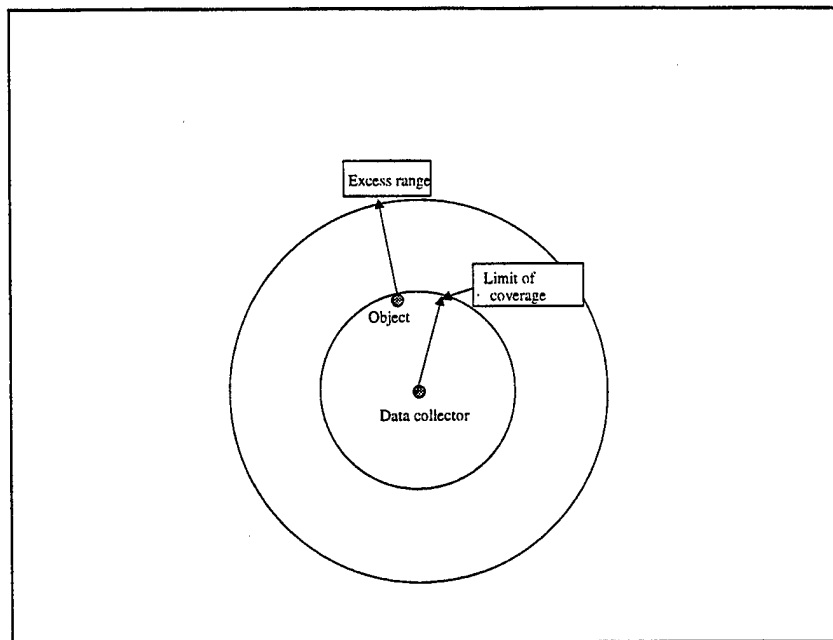


Figure 6.3-1, Signal Interception or Interference

The inner of the two concentric circles represents the largest local controlled-access area. The data collector is assumed to be located at its center. Its radius then determines the range of the communication link needed to provide location quality 1 or 4. Suppose, for the moment, that it is designed to be essentially restricted to the inner circle by the exploitation of atmospheric attenuation phenomena (i.e., ignore the inevitable additional range that results if a receivable signal is to be received at the periphery of the inner circle). All the objects to be monitored are located within the inner circle and may even be located at or near the periphery of it. If, for practical reasons, they employ omni-directional antennas and have sufficient range capability to be received by an omni-directional antenna at the center of the circle, then they will also be interceptable within a circle centered at their own location and of similar radius to the inner circle. This is shown in the figure as "excess range," and amounts to an operating area for unfriendly interceptors and data corrupters. Denial operations could presumably be mounted from even longer ranges since higher power levels would be used for it. The power requirement for such an operation is not, however, simply based on space loss. There is also the atmospheric loss to be overcome and that may be significant. It should be noted that the circular geometry used here is the most favorable to the security of the link since the maximum required range equals the minimum, and the operating area available for IW operations is minimized for the given total area. There are, therefore, unavoidable threats of interception, jamming, and surreptitious data corruption associated with using RFID at longer ranges.

Dedicated optical links seem to be destined primarily for indoor use due to atmospheric attenuation and weather effects. But if they find outdoor employment, they will ordinarily have very strict beam (i.e., pattern) control. Interception or corruption usually requires getting into the actual beam since any scattered energy is of such low intensity and subject to absorption. These considerations prompt an across-the-board judgment of "High" for these links in the matter of transmission security.

Commercial cell phone links are judged to provide questionable security. This is due primarily to the fact that they are not under AF control. There are two areas of cell phone operation where transmission security is a question. There is the cell phone network that the signal is in after reception at one of the network nodes, and there is the direct signal from the cell phone itself. The first of these areas presents serious problems to unsophisticated, independent IW operators, that is operators working outside the network. A technologically advanced opponent, on the other hand, may be able to penetrate the network; although there is some evidence that this is becoming much more difficult for even the sophisticated opponent (Kocks, 2000). The second area, the direct signal from the cell phone, is subject to the same considerations as the simplified example given earlier – without the option of frequency selection. In view of these factors, as well as the fact that there may be no cell phone service in a deployment area, cell phone communication links are rated as "Medium" in transmission security, and are not recommended for deployable AIT systems.

6.3.4 Supportability/Reliability

Supportability carries the ideas of system robustness, reliability, difficulty of repair, spares requirements, and so on. Of these, only reliability and error probability depend strongly upon choice of communication structure. These consequently are the only elements of supportability that are included in this electromagnetic spectrum analysis. The systems based on wire or cable are generally "High" in availability and "Low" in error probability (or rate). The fiber optic systems, in fact, may be said to have "Very Low" error probability. The wireless systems, on the other hand, are "Variable," depending heavily upon frequency selection. When locally accessible, however, a commercial cell phone system might be expected to have "High" availability and "Low" error probability.

6.3.5 Safety

Safety issues associated with the use of electromagnetic energy in AIT systems include the threats of accidental munitions detonation or fuel ignition, as well as more direct modes of damage to personnel in the vicinity of the technology. These latter effects include actual physical damage to human tissue caused by EM heating. This could include damage to eyes by general RF heating or to the retina by light amplification by stimulated emission of radiation (LASER) heating, as well as indirect impacts on natural or stimulated body rhythms (e.g., brain waves or pacemaker signals). None of these issues appear to pertain to AIT systems based on wire/cable communication. These systems are therefore rated "High" or "Very High" in safety. Wireless systems are a different matter. Transmissions from "wireless sensors" are almost all of very low power and duty cycle, and would seem to offer little threat to either humans or materiel. But scanners employing a LASER beam to scan bar codes at ranges of a few meters might pose a threat of retinal damage to careless personnel. Cell phones have received significant scrutiny in the past couple years. These phones also operate with low power (although much higher than the wireless sensors mentioned earlier), but when employed for voice communication they are held close to the head of the user. They, therefore, deserve a closer consideration. While the threats of accidental munitions detonation or fuel ignition are not beyond the scope of this survey, no information pertaining to them was found, and they are not discussed further. The safety of systems based on wireless communication technologies is for these reasons shown as "Variable."

Foster & Moulder (2000), writing in the August 2000 issue of *IEEE Spectrum*, examine the question of mobile phone safety. They note that the frequencies radiated by cell phones fall

between those radiated by microwave ovens and TV transmitters, and continue on to say that such radiation "can induce biologically significant heating." Reuters (2000) reported recently on research published in *The Lancet* by physicist Dr. Gerard Hyland. Dr. Hyland observes that "children who use mobile phones risk suffering memory loss, sleeping disorders, and headaches." He attributes these difficulties not to brain heating but to the effects of low intensity radiation on the rhythms of the brain, to which children are particularly vulnerable. He does not say that only children are vulnerable. Dr. Hyland's research is the most recent to question mobile phone safety, and his results do not seem yet to be widely accepted.

Cleveland & Ulcek (1999) present a more official position in a Federal Communication Commission publication. They note extensive tests have been conducted on hand-held radios operating at different frequencies "in order to determine the amount of RF energy that might be absorbed in the head of an individual using one of these devices." The results rate an extended quotation.

"The only potential hazard found could occur in the unlikely event that the antenna tip was placed directly at the surface of the eye. Other studies ... have concluded that during routine use of hand-held radios exposures would normally be in compliance with accepted safety guidelines. Significant absorption might occur if the transmitting antenna of the radio were placed within a distance of about 1-2 centimeters (less than an inch) from the head or eye. However, this would be a very unlikely user position, and even if it occurred the overall time-averaged exposure would probably be acceptable. Therefore, if hand-held radios are used properly there is no evidence that they could cause hazardous absorption of RF energy." (Cleveland & Ulcek, 1999, p. 28)

Regarding reports of possible interference from digital RF devices such as cellular telephones to implanted cardiac pacemakers, a joint industry/Food and Drug Administration (FDA) team investigated "whether such interference could occur, and, if so, what corrective actions could be taken." The team concluded that "One of the primary recommendations is that digital wireless phones be kept at least six inches from the pacemaker and that they not be placed directly over the pacemaker, such as in the breast pocket, when in the 'on' position. Patients with pacemakers should consult their physician or the FDA if they believe that they may have a problem related to RF interference." (Cleveland & Ulcek)

Hence, while there is controversy over the safety of some of the wireless technologies, the probable direct threat to personnel is "Variable" but small in all cases, and the safety of the wire/cable-based communication technologies is generally "High."

6.3.6 Conclusion

The conclusions of this communications technology assessment with respect to operational criteria are summarized in Table 6.3-1, *Classes of Communication Links*. Table 6.3-1 is supported by the contents of Table 6.2-3, *General Spectrum Characteristics*, and Table 6.2-4, *Frequency Response to Operating Environment*.

The results of this electromagnetic spectrum analysis provide general guidance for structuring an overall AIT system to support logistics operations. Any specific system design requires a detailed engineering analysis that is beyond the scope of this survey.

7. TECHNOLOGY PARAMETER ANALYSIS

This portion of the report discusses the parameters and operational characteristics (technical properties) of candidate technologies. The technical properties were derived from a number of sources and sometimes could be only inferred from the technology developer/vendor information. It was originally planned that a direct match of candidate technologies could be made to the objects identified earlier in this report. Such a direct match would allow an easy selection of specific technologies (and vendors) to track and report on specific objects. As it turned out, individual AI technologies were found to be only pieces of a potential overall architecture. The technical properties described here, therefore, only allow the reader to select general data collection/transmission techniques for a particular requirement that the reader can explore further with AIT vendors. Table 7.1-1, *Technology Parameters*, (see page 47) summarizes the information discussed in this portion of the report.

7.1 Parameter Description

Sensing technologies may, in principle, be appropriate for any operational object. Determination of that appropriateness depends upon the operational need for information about the object, as well as the operational capabilities of the given technology. In order for a technology to be appropriate for use with a given class of objects, the technology must be capable of providing at least the minimum required information reliably, safely, securely, and economically. (Note: A technology having greater than the minimum required capability might well be applicable to a class of objects while not being economical.) For this reason, parameters fundamental to these aspects of the performance of both objects and technologies are relevant to the consideration. The natural source for information concerning the objects of interest is a concept of operations. In the absence of an approved concept document, it has been necessary for the study team to construct a notional one. Although our concept of exploration has received no official validation, it has been compared informally with available LOCIS documentation and found to have captured the essential points of it. Information on the available technologies has been collected as part of the present survey.

Each object and technology is described in terms of its operational characteristics and a set of state variables—location and identification. For each state variable, the performance requirement is given for objects, and the performance capability is given for technologies. Parameters that have no naturally discrete values are roughly quantified. It should also be noted that neither the choice of descriptive parameters nor the units of measure are sacred. Their only virtue lies in the fact that they open a window on the reliability, safety, security, and economy with which a technology may be applied to a class of operational objects. The descriptions that follow provide background for interpreting the tabular entries of Table 7.1-1, *Technology Parameters*. Explanations of the column entries immediately follow the table in a series of notes.

Table 7.1-1, Technology Parameters

Technologies	Capacity	Range	Standard	Maturity	Reliability	Security	Safety	Strengths	Weaknesses	ID	Location	Cost	Deployability
Bar Code Identification Technologies													
2D	1850 characters (char)	Close: Line of Site (LOS)	PDF-417	Technology Readiness Level (TRL) 9	Med	N/A	High	1, 2, 3, 4, 5, 6, 7, 8, 11	1, 4	U	1, 2 Implicit	Low to Med	High
Linear	~ 20 char	Close: LOS	Code 39	TRL 9	Med	N/A	High	1, 2, 3, 4, 11	1, 2, 3, 4	U	1, 2 Implicit	Low	High
CARD - Card Personalization Systems													
Magnetic (Stripe) Card	Various	Contact	Proprietary	TRL 9	High	N/A	High	1, 4, 6, 7, 9, 10, 13, 16	4	U	1, 2 Implicit	Low	High
Optical Memory Card (OMC)	2.4 Mbyte	Contact	DELA	TRL 9	High	N/A	High	1, 3, 4, 6, 7, 9, 10, 13, 16	4	U	1, 2 Implicit	Low	High
PC Memory Card	1 Kbyte	Contact	Proprietary	TRL 9	High	N/A	High	1, 4, 6, 7, 9, 10, 13, 16	4	U	1, 2 Implicit	Low	High
Smart Card	4 Kbyte	Contact	Proprietary	TRL 9	High	N/A	High	1, 4, 6, 7, 9, 10, 13, 16	4	U	1, 2 Implicit	Low	High
Radio Frequency Identification (RFID) (See Note H)													
Active	< 128 kbyte	1-300' Omni	None	TRL 9	High	N/A	High	12, 13, 14, 15	8, 9	U	1, 2 Implicit	Low to Med	Med
Passive	20 byte	1-240' LOS	None	TRL 9	High	N/A	High	1, 3, 6, 10, 11, 12, 13	8	U	1, 2 Implicit	Low	Med
Biometric Identification Technologies													
Facial Recognition	N/A	LOS	Proprietary	TRL 9	Med	N/A	High	6	4, 5, 7, 8	U	1, 2 Implicit	Med to High	Low to Med
Voice Print	N/A	N/A	Proprietary	TRL 9	Med	N/A	High	6	4, 5, 8	U	1, 2 Implicit	Med to High	Low to Med
Finger and Hand Print	N/A	Contact	Proprietary	TRL 9	Med	N/A	High	6	4, 5, 7, 8	U	1, 2 Implicit	Med to High	Low to Med
Iris and Retina Print	N/A	Near-contact	Proprietary	TRL 8 / 9	Med	N/A	High	6	4, 5, 7, 8	U	1, 2 Implicit	Med to High	Low to Med
Penn State University Research Program (See Note A)													
Fractal Antenna (for passive responder)	N/A	Close	None Known	TRL 4	High	N/A	High	Unknown	Unknown	N/A	1, 2 Implicit	Unknown	Unknown
Surface Acoustic Wave Passive Responder	TBD	N/A	None Known	TRL 4	Med	N/A	High	Unknown	Unknown	U	N/A	Unknown	Unknown

Table 7.1-1, Technology Parameters (continued)

Technologies	Capacity	Range	Standard	Maturity	Reliability	Security	Safety	Strengths	Weaknesses	ID	Location	Cost	Deployability
Dominant Location Technology													
Global Positioning System (GPS) (See Note B)	Extensive	Long Range (LR); LOS		TRL 9	High	N/A	High	3, 4, 14, 16	8	N/A	6	Low to Med	Med to High
Data Sensing/Recording Technologies													
Speech Recognition	N/A	Close	None Known	TRL 8 / 9	Medium	N/A	High	6, 7, 12, 17	4, 10	O	N/A	Med	Med to High
Optical Character Recognition	N/A	Close	None Known	TRL 9	High	N/A	High			N/A	N/A	Low	Med to High
Portable Data Collection Devices	N/A	Close	None Known	TRL 8 / 9	High	N/A	High			N/A	N/A	Unknown	Unknown
Wireless Sensors (Arthur D. Little Briefing)	N/A	Variable	None Known	TRL 8 / 9	High	Variable	High	N/A	N/A	U	N/A	Unknown	Unknown
Personnel State Monitors													
Headband EEG and Oximetry (See Note C)	N/A	Data Trans.	None Known	TRL 9	Unknown	Unknown	Unknown	Unknown	Unknown	N/A	N/A	Unknown	Unknown
Voice Stress and Content Analysis	N/A	Data Trans.	None Known	TRL 7	Unknown	Unknown	Unknown	Unknown	Unknown	N/A	N/A	Unknown	Unknown
EKG, EMG, Thoracic Impedance Cardiography	N/A	Data Trans.	None Known	TRL 8	Unknown	Unknown	Unknown	Unknown	Unknown	N/A	N/A	Unknown	Unknown
Actigraph - Physical Activity/Sleep Deprivation	N/A	Data Trans.	None Known	TRL 9	Unknown	Unknown	Unknown	Unknown	Unknown	N/A	N/A	Unknown	Unknown
Foot Contact - Weight/Locomotion	N/A	Data Trans.	None Known	TRL 7	Unknown	Unknown	Unknown	Unknown	Unknown	N/A	N/A	Unknown	Unknown
Panic Button (for casualties)	N/A	Short	None Known	TRL 5	Unknown	Unknown	Unknown	Unknown	Unknown	N/A	N/A	Unknown	Unknown
Data Transmission/Communication Technologies (See Notes D, E, and H)													
Cell Phone	N/A	Variable	N/A	TRL 9	High	Variable	Med	1, 4, 14, 17	4	N/A	N/A	Low to Med	Low
Telephone	N/A	Variable	N/A	TRL 9	High	Variable	High	1, 4, 14, 17	4	N/A	N/A	Low to Med	Med to High
Dedicated RF - Narrow Band	N/A	Variable	N/A	TRL 9	High	Variable	High	1, 4, 14, 17		N/A	N/A	Low to Med	High
Dedicated RF - Spread Spectrum	N/A	Variable	N/A	TRL 9	High	Variable	High	1, 4, 14, 17		N/A	N/A	Low to Med	High
Dedicated Wire	N/A	Variable	N/A	TRL 9	High	Variable	High	1, 4, 14, 17		N/A	N/A	Low to Med	Med to High
Dedicated Infrared (or other electro-optic)	N/A	Short	N/A	TRL 9	Medium	Variable	High	1, 4, 14, 17	7	N/A	N/A	Low to Med	Med
Integrated AIT System Architectures													
Wireless Real time locating System (See Note F)	N/A	LOS; LR	Proprietary	TRL 9	High	N/A	High	4, 6, 9, 10	8, 10	U	4 (S)	High	Low
Wireless Real time locating System (See Note G)	N/A	LOS; LR	Proprietary	TRL 9	High	N/A	High	4, 6, 9, 10	8, 10	U	6	High	Med
Satellite Tracking System	Extensive	LOS; LR	Proprietary	TRL 9	High	High	High	4, 6, 9, 10, 15, 16, 17, 18	8, 10	U	6	High	Med to High

Table 7.1-1 Explanations

Note A Penn State Research Program. These devices represent development of miniaturized components for doing passive RFID.
 Note B Questions concern Reliability in wartime.
 Note C Range depends on the Data Transmission technology employed.
 Note D Discussed in the Electromagnetic Spectrum Analysis.
 Note E Cell Phone safety remains controversial. Do not use in flammable vapor areas.
 Note F Bus Tracker Solution Web Site: <http://www.tss-tag.com/>
 Note G WhereNet Web Site: <http://www.wherenet.com/homefr.htm>
 Note H Safety is a concern when using RF signals near certain munitions items, hazardous materiel, and flammable vapors.

Data trans.	Depends on data transmission method
Code 39	www.makebarcode.com/specs/code_39.html
LOS	Line of Sight, but not a propagation mode. Scanner must be aimed at device.
LR	Long Range, to imply very long range - e.g., transoceanic or transcontinental.
PDF-417	www.ait.std.caci.com/public/pdf417.htm

Strengths		Weaknesses	
1	Inexpensive	1	No updates
2	Disposable	2	Low tolerance to damage
3	Established standards	3	Pre-position data required for effectiveness
4	Part of DoD or commercial business practice	4	Human involvement required.
5	Several layers of redundancy	5	Read/writer not portable (requires PC)
6	Durable	6	Slow data transfer rate
7	Pre-positioned data not required	7	Line of sight interrogation
8	2D scanners can also read linear bar code	8	Moderately expensive
9	Able to withstand harsh environments	9	Battery required for interrogation
10	Quick data transfer rates	10	Expensive equipment needed in each vehicle to allow communication between dispatcher and host system.
11	No battery required for interrogation		
12	Some read/write capability		
13	Reusable		
14	Omni-directional interrogation		
15	No human involvement required		
16	Precise location of conveyance		
17	Two-way communication		
18	Able to redirect vehicle in minutes		

Personnel State Monitors:

Lawlor, Maryann. "Personal Physiological Monitors Find Warfighter Effectiveness Edge."
SIGNAL. Vol. 54, No. 12, August 2000.

<http://venable.utmb.edu/Students/Monitoring/06oximetry.html>

EEG - Electro-encephalography	(Brain)
EKG - Electro-cardiogram	(Heart)
EMG - Electro-myography	(Muscle)

Maturity Technology Readiness Level (TRL)

TRL 1, 2, 3	Basic Research
TRL 4, 5	Component Level Brassboard
TRL 6, 7	System/Subsystem Prototype
TRL 8	Newly on Market
TRL 9	Established in Market

Table 7.1-1 Explanations (continued)

Location Category / Definition	
1 (S)	Object is "inside"/"not inside" of the largest (size) local controlled-access area (e.g., air base)
2 (S)	Object is "inside"/"not inside" of one or more relatively small (size) controlled-access areas. (e.g., motor pool, or warehouse) either inside or outside the largest local area.
3 (A, S)	Object is in a specific location (accuracy) within a small (size) controlled-access area.
4 (A, S)	Object is in a specific location (accuracy) within the largest (size) controlled-access area.
5 (A, S)	Object is in a specific location (accuracy) within an area (size) surrounding the largest controlled-access area.
6 (A, S)	Object is in a specific location (accuracy) within a very large (size) area – worldwide.

ID:	
U	- Unique: Can identify an exact object (i.e., F-15E, serial # 85-0345)
O	- Type: Can identify a type - totally interchangeable

7.2 Operational Characteristics

The survey has turned up quite a range of technologies. They are not all nicely-describable in terms of the criteria listed in the Statement of Work. In fact, there are few complete AI technologies. What appear in the survey are components applicable to an AIT system rather than actual integrated systems. It should not be surprising, then, to find that different types of components are described in terms of different subsets of the following list of operational characteristics.

7.2.1 Data Storage Capacity

Data storage capacity is given in bytes or some multiple thereof, such as kilobytes or megabytes. Linear bar codes are sometimes thought of as similar to read only memory (ROM) with a capacity of around 100 bits. An alternative view is to think of them as identifying marks capable of a variety of values determined by their ROM capacity.

7.2.2 Transmission Range

This parameter refers only to wireless transmission modes and is concerned with two aspects of AIT transmission. A related issue of transmission method is also included in the range discussion if appropriate. Methods include line of sight (LOS), RF, inductive magnetic field, acoustic, etc. There are two aspects of transmission in the AIT context.

- Transmission as part of the sensing activity, such as RF or IR interrogation of some device on an object, or optical scanning of a bar code. This is generally a wireless technique.
- Transmission as conveying the sensed information to the facility. This form of transmission may employ any transmission method.

7.2.3 Standard

If a national or international standard has been found for the technology, it is identified.

7.2.4 Maturity—Technology Readiness Level (TRL)

Generally, the less time a technology has been in development, the less information is available on it. The TRL numbers listed in Table 7.2-1, *Technology Readiness Levels*, are used in the maturity column of Table 7.1-1, *Technology Parameters*, to indicate the level of maturity of the given technology. The TRL schema was adopted from the National Aeronautics and Space Administration's (NASA) 1991 Integrated Technology Plan.

Table 7.2-1, Technology Readiness Levels

Technology Readiness Level (TRL)		Description
Basic Research	TRL 1	Basic principles observed and reported
	TRL 2	Technology concept and/or application formulated
	TRL 3	Analytical and experimental evidence for critical function and/or characteristic proof of concept
Component-Level	TRL 4	Component and/or breadboard demonstrated in laboratory environment
	TRL 5	Component and/or breadboard validation in relevant environment
System/Subsystem Prototype	TRL 6	System/subsystem model or prototype demonstration in a simulated environment (level where AFRL transitions)
	TRL 7	System validation model demonstrated in an operational environment
Newly on Market	TRL 8	Actual system completed and newly in the market
Established in Market	TRL 9	Actual system established in the market

7.2.5 Reliability

Reliability may refer to the ruggedness of the technology, such as the mean time between failure (MTBF), indicating how well it holds up to field use (temperature, moisture, dirt, impacts), etc. It may also refer to its ability, even when operating properly, to adequately perform its function. An infrared sensor may be completely operational and yet unable to sense through a dense fog.

7.2.6 Security

This feature most naturally refers to the security of the logistic data from denial, interception, or manipulation by an enemy. As a consequence it refers primarily to methods of data transmission and is treated in terms of security risks. For this study it is given as low, medium, or high.

7.2.7 Safety

Safety has been interpreted as concerning personnel in the vicinity of the technology. Does the AIT system or component threaten the physical well being of the user? Most AI technologies have no inherent risk to the object being tracked, the personnel in the immediate area, or the environment. We hasten to remind the reader that certain types of munitions items, hazardous materiel, and flammable vapors may be excited by RF energy. For this reason, the use of RF devices should be examined carefully.

7.2.8 Strengths

We assembled a numbered list of items considered strengths of the given technology. Where appropriate, the numbers are entered in the table.

7.2.9 Weaknesses

We assembled a numbered list of items considered weaknesses of the given technology. Where appropriate, the numbers are entered in the table.

7.3 State Variables

State variables include the ability to ascertain the object's identity and then determine where that object is within some boundary.

7.3.1 Identification

Table 7.1-1, *Technology Parameters*, uses the same categories as those listed for objects in Table 4.3-1, *Objects, Characteristics, and Variables*: Unique, Unique within a Type, Type, and Info. Refer to section 4.3.1 for an explanation of each category. For this area, however, we identify whether the technology can report the category.

7.3.2 Location

Table 7.1-1 also uses the same location categories as objects listed in Table 4.3-1, *Objects, Characteristics, and Variables*. Each type of object to be tracked has its own peculiar location requirement. Similarly, each technology we evaluated has its own peculiar location-reporting capability. The purpose of this discussion is to exploit these ideas by developing a set of location categories that can be used to describe the location-reporting capabilities of the technologies. The idea is that if the location-reporting capability of a given technology matches the location requirement of a given object, then there is a potential match.

In some instances the location category for a technology may be suggested by existing methods of using that technology. Bar codes, for example, are primarily an identification technology, but they may also suggest location by implication. In use, either the bar code must pass a scanner, or the scanner must be brought to the bar code. In the first case, the location of the scanner is ordinarily known to be at some choke point (e.g., checkout lane at the grocery or warehouse, or the entrance/exit of a motor pool, or even an air base main gate). As the object passes the scanner, its location at the time of passage is known to within a distance equal to the scanning range. But more importantly it is also known that this specific (i.e., identified) object is entering or leaving a controlled-access area such as a grocery store, warehouse, hangar, or perhaps the motor pool. If, on the other hand, the scanner is brought to the bar code, then the object associated with the bar code will be identified. But unless it is known that the scanner is within the controlled-access area, or the scanner has a location-determining capability, such as integrated GPS, there will be no location information.

This example suggests a candidate for a least restrictive category of location; the object is "inside"/"not inside" the largest local controlled-access area (e.g., air base). This would be the location information produced by a bar code reader located at each entrance/exit of the area. It is worth noting that not all the objects in the current list are capable of being located using this technique. Aircraft, for example, will not ordinarily enter or exit the base through the main gate. In principle, one could place a special scanner at each runway threshold to scan bar codes on the bottom of arriving and departing aircraft if this level of location quality were adequate.

Implicit location reporting can be used but is sometimes not accurate enough. Knowing that an object is within a large area may not be useful. Only a more active type of technology can identify exact locations explicitly. Examples of such technology are RFID, GPS, triangulation, etc. Using the aircraft analogy again, scanning a bar code as it crosses the runway threshold tells you implicitly that the aircraft is on the base. It wasn't on base before; it was just read at a base entrance, therefore it must now be on the base. If the aircraft Identification Friend or Foe (IFF) or

another electronic RFID/GPS unit onboard were to broadcast the aircraft's ground location when the weight-on-wheels circuit is closed, the exact location would be explicitly known.

Continuing this line of thought provides a set of progressively more demanding location requirements. Table 7.3-1, *Technology Location Categories*, is intended to provide an abbreviated naming convention for the items in the list, one that also allows for specification of size (S), or accuracy and size (A, S), as required. Location accuracy need only be a gross estimate. It probably should not be specified as a distance less than the size of the associated object. Practically speaking, civilian GPS accuracy (or at worst, inertial navigation accuracy) probably dominates this specification for all cases outside the local air base.

Table 7.3-1, Technology Location Categories

Category	Definition
1 (S)	Object is "inside"/"not inside" the largest (size) local controlled-access area (e.g., air base)
2 (S)	Object is "inside"/"not inside" one or more relatively small (size) controlled-access areas (e.g., motor pool, or warehouse) either inside or outside the largest local area
3 (A, S)	Object is in a specific location (accuracy) within a small (size) controlled-access area
4 (A, S)	Object is in a specific location (accuracy) within the largest (size) controlled-access area
5 (A, S)	Object is in a specific location (accuracy) within an area (size) surrounding the largest controlled-access area
6 (A, S)	Object is in a specific location (accuracy) within a very large (size) area – worldwide

7.4 Practicality of Application

For recognized matches of technologies with objects, there remains the question of practicality. This study is concerned with three major aspects of practicality: cost, deployability, and supportability. Where possible, these aspects are assessed.

7.4.1 Cost

This area is very difficult to state. AIT developers and vendors like to talk in terms of high, medium, or low cost and are reluctant to define their terms. Reliable cost information, therefore, is not readily available for most technologies, and those cost figures that have been found pertain generally to components rather than systems. Because of this lack of information, we are unable to perform cost analyses of complete AIT systems.

7.4.2 Deployability

Deployability is concerned with how readily an AIT system, based on the given technology, can be deployed to another site. Such sites are probably outside the CONUS, with different local geography, weather, information warfare threat, etc. Rapid deployability would seem to require wireless data transmission, attention to security from enemy manipulation, and minimal setup time for sensors. These considerations may simply rule out some of the conceivable technologies.

7.4.3 Supportability

System robustness, reliability, difficulty of repair, spares requirements, and so forth, are factors affecting supportability. As before, these factors may be judged with respect to possible components, but probably only indirectly with respect to notional systems. This factor may be the only one more difficult to quantify than cost. Thus far, no vendor has been found to say that their product(s) have supportability issues. Quite the opposite in fact – they all tout the ruggedness and reliability of their products in the field. Because no meaningful parameter could be derived, this area is addressed by exception and only for specific technologies.

8. TECHNOLOGY APPLICATION TO LOCIS REQUIREMENTS

8.1 Overview

Early LOCIS efforts concentrated on the flow of legacy data systems in direct support of sortie production functions. Our concept of exploration considered the same sortie production functions and added the factor of mobility processing, but we did not investigate data system operations or interoperability. The information presented in this section of the report (a subset of our total study) relates some of the technologies we feel will be useful to further development of the LOCIS efforts for monitoring locations and status of equipment and people.

8.2 Requirements Definition

The LOCIS technology requirements listed in Table 8.2-1, *LOCIS Requirements and Candidate Solutions*, were taken from the 21 December 1999 Concept of Operations (CONOPS) Version 12.0 for Logistics Control and Information Support (LOCIS). The CONOPS (see Appendix C of this report) is a living document that is periodically updated. The reader may contact the CONOPS author at AFRL/HESR to obtain the most recent version. Many, if not most, of the requirements can be filled by using current technology that does not truly belong to the passive AIT world, such as pagers, cell phones, automatic feeds among various legacy information systems, and standard desktop or laptop computers. Because our search for AI technologies also included some of these items, we offer some suggestions for choosing among them. More to the point of this study, however, some of the requirements (speech recognition, speaker recognition, etc.) can take advantage of AI technologies to simplify operations.

Table 8.2-1, LOCIS Requirements and Candidate Solutions

LOCIS REQUIREMENT	AIT CANDIDATE SOLUTION
Feeds from legacy information systems	No AIT solution
Text Pager (color capable?) Could not find color capable	Commercial technology [Black and white (B/W) only] Combine with cell phone and/or PDA Numerous vendors exist
Cell Phone	Commercial technology Combine with pager and/or PDA Numerous vendors exist
Pager/cell phone system (color capable?) Could not find color capable	Commercial technology (B/W only) Numerous vendors exist. Visit the MSN e-shop at: http://eshop.msn.com/softcontent/softcontent.asp?scmlId=224&scpld=508

Table 8.2-1, LOCIS Requirements and Candidate Solutions (continued)

LOCIS REQUIREMENT	AIT CANDIDATE SOLUTION
Wireless personal digital assistant (Palm, etc.)	Windows® CE based PDA, pocket PC, tablet PC, etc. For a good e-shop, try the following: http://eshop.msn.com/category.asp?catid=40 For a web site that appears to concentrate on Palm-related topics: http://palmtops.about.com/gadgets/palmtops/ For a rugged wireless tablet PC (Sidearm): http://www.melard.com/ An excellent magazine on small computers, PDAs, and "things" is <i>Pen Computing Magazine</i> (also has web site full of information): http://www.pencomputing.com
Personal communicator	Not sure what this is; sounds like cell phone, PDA, radio, etc. See above items for them. Versus has a short range comm badge system: http://www.versustech.com/locating.htm ParkWatch, Inc. has personnel locator system: http://www.parkwatch.com/
Wing operations center (WOC) Wall Display Panels	No AIT Solution Numerous vendors of computer display devices
Voice (speech) recognition and speaker recognition	Lawrence Livermore National Laboratory: http://www.llnl.gov/IPandC/op96/04/4e-spe.html and http://speech.llnl.gov/ Also commercial firms/web sites: http://www.speakerkey.com/ and http://www.verivoice.com/
Desktop office personal computer	Numerous commercial computer vendors Add biometrics technology for automated secure logon, voice/speech recognition For biometrics information: http://www.biometrics.org/ and http://webusers.anet-stl.com/~wrogers/biometrics/
Computer logon authorization	Fingerprint, iris scan, speech or speaker recognition: http://ethentica.com/product.htm http://www.iriscan.com/ http://www.identix.com/itsecurity/products/index.html
Internet connectivity	Netscape, Internet Explorer Wireless LAN/WAN
E-mail	Default government system Microsoft Windows®, Lotus, GroupWise Wireless LAN/WAN
Office suite of shared files	Default government system Microsoft Windows®, Lotus, GroupWise

Table 8.2-1, LOCIS Requirements and Candidate Solutions (Continued)

LOCIS REQUIREMENT	AIT CANDIDATE SOLUTION
Report change of equipment status mission capable (MC) awaiting maintenance (AWM) awaiting parts (AWP)	RFID, wireless LAN/WAN Central point for RFID information: http://personal.paclink.net/~jimeagle/rfid_mfg.htm A good commercial firm for RF hardware: http://www.rfcode.com Symbol Technologies wireless LAN (IEEE 802.11 wireless LAN standard) info: http://www.symbol.com/products/wireless/wireless_portfolio.html
Reporting mobility processing of pallets and unit type codes (UTCs)	RFID (active tags), wireless LAN/WAN Central point for RFID information: http://personal.paclink.net/~jimeagle/rfid_mfg.htm A good commercial firm for RF hardware: http://www.rfcode.com Symbol Technologies' Spectrum24® Wireless LAN (IEEE 802.11 wireless LAN standard) info: http://www.symbol.com/products/wireless/wireless_portfolio.html
Reporting mobility processing of people	Smart card, optical memory card, RFID: http://www.smart-card.com/ http://www.srcorp.com/Navigat.html http://www.lasercard.com/ http://personal.paclink.net/~jimeagle/rfid_mfg.htm USAF AEF Battlelab tool (DPART): http://www.mountainhome.af.mil/aeafb/

8.3 Recommended Solutions

Although we found few full up and running AI technology suites to satisfy a LOCIS architecture requirement, we did find a number of technologies that could augment the LOCIS efforts. They are summarized in Table 8.2-1. For many AI candidate solutions, we provide Internet hyperlinks to product information.

There are many vendors of standard computers and display monitors or panels; we did not pursue them. Likewise, we did not pursue pagers or cell phones beyond a quick review to see if new technology might augment an AI solution. Numerous providers of pagers, cell phones, and combination units exist. Some of them have rudimentary voice recognition to assist with number dialing. Some development for future products promises additional features within a cell phone-sized product. An interesting look at the future is at the Symbian, Inc. Internet site at http://www.symbian.com/trends/symb_devices.html. We did not find reference to color display capability for any pager or cell phone device.

The LOCIS CONOPS mentions the use of Palm devices. We have combined Palm, pocket PCs, tablet PCs, and laptops into a LOCIS requirement for wireless PDAs. Although PDAs are not AI technology, they can be used with great success to satisfy the LOCIS requirement for passive information flow. The choice of which type of PDA to use should be examined carefully for appropriate operating system (Palm, Windows®, or EPOC), ruggedness, data security, etc. Because the information to be shared contains graphics, color-coding, and will likely use Microsoft-compliant text/data, we recommend the use of a Windows® CE-based product. Most

of the typical PDAs are not rugged, and they have small display areas, restricting the kinds and amount of information displayed. For those individuals requiring a rugged device and/or a larger display area, the wireless Tablet PC (Sidearm) by Melard, Inc. would be a good choice. The Sidearm weighs only 2.4 pounds and is rugged, impervious to moisture, and has a relatively large screen display. An excellent source of information about hand-held computers (PDAs, pocket PCs, tablet PCs, notebooks, and accessories) is *Pen Computing Magazine* at <http://www.pencomputing.com>.

Portable wireless PDAs have inherent security issues, including theft and user authentication. In addition to the normal UserID and Password security procedures, we recommend the LOCIS architecture use technology being developed and marketed to positively identify a speaker's voice. The Lawrence Livermore National Laboratory is developing devices to do just that. Their web sites at <http://www.llnl.gov/IPandC/op96/04/4e-spe.html> and <http://speech.llnl.gov/> discuss their progress and indicate a desire to collaborate with others for further study. Additionally, a number of commercial vendors of voice and speaker identification technology exist, two of which are ITT Industries (<http://www.speakerkey.com/>), and VeriVoice, Inc. (<http://www.verivoice.com/>). PDAs are being developed with voice recognition capabilities and could take advantage of the additional security either of these companies' products provides.

Additional biometrics technologies for personal identification (for desktop computer situations) include two fingerprint recognition developers, Identix, Inc. (<http://www.identix.com/>) and Ethentica, Inc. (<http://www.ethentica.com/>), and an iris-scanning system developer Iridian Technologies, Inc. (<http://www.iriscan.com/>).

The Biometrics Consortium (<http://www.biometrics.org>) serves as the U.S. Government's focal point for research, development, test, evaluation, and application of biometrics-based personal identification and verification technology. This organization is an excellent source of information on how to plan for and implement the latest (or still developing) technologies.

An item related to PDAs, cell phones, was identified in the LOCIS CONOPS as a personal communicator. Two companies market products that might be of interest to a LOCIS architecture, although they are not exactly communicators. First is ParkWatch, Inc., which markets a personal locator device (the size of a wristwatch) used by commercial operations to track individuals within specified boundaries. The device successfully locates people to within ten feet at a 65-acre water theme park, using just 12 antennas. This product is highlighted at the ParkWatch, Inc., web site (<http://www.parkwatch.com/>). In brief, the device contains a small, active RF chip allowing fast, passive, electronic searches. There is no voice communication, but this could be useful in finding someone in a hurry, a sometimes difficult or impossible task if that individual doesn't have a radio. Versus Technologies, Inc. is another company marketing personnel and equipment tracking devices. Their device (IR and RF) is also quite small and the tag marketed for tracking people has a limited communication capability. Additional information is at the Versus Technologies web site (<http://www.versustech.com/locating.htm>).

The areas where we can offer AITs as candidate solutions to the LOCIS requirements include passive reporting of equipment status changes and the mobility processing of both people and equipment. All three areas could use RFID equipment to collect and transmit information automatically on a timed basis (by defining set intervals) or when polled by a central system. The change of equipment status would still likely be first reported manually by some individual to a computer database either through a keyboard or via voice recognition. This changed status could also be electronically written to an RFID tag or smart card attached to the unit. The RFID tag or smart card (which has an embedded RF chip) could store the maintenance history or periodically

report as programmed. The information could be passed as needed to central command centers and mobile users via a wireless LAN/WAN.

To track the processing of mobility equipment and pallets, RFID tags can be used successfully, especially if they are read/write tags. The tag can be obtained with a locked portion of a memory that would identify the item (equipment, box, or entire pallet). A read/write tag also has a portion of memory that could be updated quickly as the item is prepared for packing, placed on a pallet, passed through a choke point, or any number of other events. The tag would then broadcast that information either on a timed basis or when polled by a stationary point. A wireless LAN/WAN would be used to gather the information and distribute it just as with the equipment maintenance scenario described in the paragraph above. A deployable set of antennas, reader/interrogators, and an information concentrator (server/hub) could carry this concept further. The mobile system could collect information from the destination site and report it to a home station using either hard-wired or wireless LAN/WAN.

To track personnel processing through a mobility line, we recommend using smart cards or optical memory cards. These are not really passive since they generally require contact or near contact for read/write operations. As the technology develops, however, the read/write ranges will expand to where an individual's ID card containing a memory chip will be able to transmit a number of feet. This card can contain personal identification data as well as access to the medical, training, and special qualification information. As the individual passes through the mobility processing stations, a central database can be automatically updated with the appropriate information. This data then automatically builds the load manifests, updates the mobility tracking systems, etc. The Mountain Home Air Force Base Air Force Expeditionary Force Battle Lab and Hurlburt Field's 16th Special Operations Wing jointly tested this concept quite successfully. We recommend this concept be adopted and tested further.

There are a number of developers and vendors for RFID and wireless LAN/WAN products. Table 8.2-1, *LOCIS Requirements and Candidate Solutions*, lists some of them. The Internet web sites listed should be visited to gain knowledge of the companies and products, but we recommend the AFRL contact Symbol Technologies, Inc. to design, field, and test a real solution.

In 1999, the DoD awarded Symbol Technologies Inc. a five-year contract with an authorized maximum of \$248 million over the term. Symbol agreed to supply a complete line of wireless mobile computing and scanning systems to meet military applications. The Symbol Technologies contractual vehicle may be useful to further develop the LOCIS solutions. Their Internet web site is: <http://www.symbol.com/index.html>.

9. CONCLUSIONS

9.1 AI Technology Functions

An important observation of this survey is that AITs comprise a mixed bag. That is, they are of different kinds and capabilities. The goal of AIT is to locate, identify, and determine the state or condition of things or people. Very few AIT solutions were found that could accomplish all parts of this goal, and they were strongly application specific. For the most part, the survey turned up technologies designed for one or two of the AIT goals. Bar code technology, for example, is usually at the top when AITs are listed. But bar code technology is a collection of tools used together when the AIT need can be satisfied by simply placing a recognizable marking on an object. The collection includes printers, scanners, and some sort of association of bar codes with the objects to be identified and possibly tracked. The ordinary bar code is read-only and as such is not capable of carrying any updated information. Of course a new bar code label, perhaps 2D, containing the new information could be printed and used to replace the original label, but this is well outside the limits of passive operation. Furthermore, a bar code is not capable of measuring or recording some aspect (i.e., fuel quantity) of the object on which it is placed. The bar code, therefore, is the basis of an identification technology. But, insofar as the bar code must be close to the scanner when it is read, it also provides implicit location information only at the time the bar code is read.

RFID and IRID are other standard AITs that share many of the characteristics of the bar codes. In many respects they may be thought of as extensions to the bar code technology. For one thing, they need not be read-only, although some of them are. Like the bar code, those marketed in the AIT world operate only at short ranges, though not necessarily with as short a range as the bar code. An RFID tag or badge with an active transmitter, for example, might have a range of a few hundred feet. It is not a great creative stretch to imagine a tag the size of which is not limited by being clipped to someone's shirt. If such a larger tag were being carried in a vehicle with its own electrical power, it might support additional functions, as well as greatly increased transmission range.

But the survey seems to indicate that such extensions of the basic identification technologies are mostly implicit in the AIT marketplace. The reason is that while there is a large market for inventory and personnel tracking systems, other applications tend to be more specialized and require specific synthesis. They are almost one of a kind. As a result, once the survey went beyond the basic identification technologies, only component technologies remained. A small number of specific application systems did surface, but they are not designed for military use. But the components represent the building blocks from which AF applications can be built. So without actually synthesizing model systems to support LOCIS, for example, this report provides an overview of tools from which AF-specific systems can be built. The list is broken into a set of functional categories including identification technologies, location technologies, state sensing and/or recording technologies, transmission/communication technologies, and specific architectures.

9.2 Identification Technologies

Identification technologies are primarily concerned with providing identification information about an object. This may be done by observing some marking that has been applied or otherwise associated with the object, such as a tattoo, bar code, RFID device, password, or some unique

feature naturally associated with the object, such as a fingerprint, retinal or iris pattern, or voice print. The former group would be employed when identifying equipment, the latter when identifying personnel.

9.3 Location Technologies

We have seen that rudimentary location information can sometimes be derived as a by-product of technologies whose primary purpose is identification. The bar code is the example discussed. There are, however, technologies whose primary purpose is to determine location. These include all methods of navigation and navigation aids, to include the GPS, inertial navigation, and all forms of Long Range Navigation (LORAN). Whether one or another of these technologies is relevant for some class of object in our concept of exploration depends upon the location requirements associated with that object. GPS with planned civilian accuracy can be purchased for a few hundred dollars and is probably more than adequate for any location requirement arising in this study. For this reason, it probably dominates all other location technologies, except in those cases requiring the lowest quality of location information if there are any. (See Bretz, Elizabeth A. "X marks the spot, maybe." *IEEE Spectrum*, Vol. 37, No. 4, April 2000.)

9.4 State Sensing and/or Recording Technologies

In addition to answering the "Who?" and "Where?" questions, AIT may also be expected to provide access to information on the state of the object it monitors. What is the state of operational readiness of a given aircraft at a particular location? How much jet fuel remains in fuel truck A at location B? This function alludes to sensing and/or recording a state. The idea here is that some state variables may be sensed and recorded automatically by an appropriate sensing and memory device. Others may require human intervention to record the value of a state, for example, aircraft operational readiness. The recording medium might be a magnetic stripe card associated with the aircraft or in the case of a more voluminous data requirement, a smart card, PC memory card or OMC. Each of these media would almost certainly contain identifying information, but their storage capacity far exceeds that required for mere identification. More to the point perhaps are speech recognition and optical character recognition devices. These might be used to transform spoken or printed information into digital form, and in that sense function as an intermediate recording device for state data.

Wireless sensors are an intermediate technology. They are special purpose transmission devices connected with an existing sensor in such a way that the sensed data may be transmitted to another location. An excellent review of such wireless sensors was conducted and reported by Arthur D. Little, Inc. under Technology Readiness and Sustainment (TRS) Delivery Order (DO) 13. (*TRS DO 13 Wireless Sensor Review – Interim Report* presentation to AFRL 17 August 2000, by Arthur D. Little, Inc.)

In principle, these devices might transmit at some fixed interval, when interrogated, or when the sensed parameter changes value by some predefined amount. The choice among these options should be based on an analysis of the operation supported by the system. This technology appears to be quite mature.

From another point of view, devices already exist for passively measuring all parameters of interest on an aircraft or ground vehicle, such as fuel, engine temperature, oil pressure and perhaps features of its load: How much fuel is in a fuel truck? Is the fuel contaminated? Once the step has been taken to use a larger RFID tag, other features may be added to it within cost

limitations. One appealing system design might employ a PDA with an associated GPS receiver and transceiver to collect this parametric information and transmit it, according to some protocol, to a data center.

9.5 Transmission/Communication Technologies

However the data may have been sensed and recorded, there remains the problem of forwarding it either directly or through intermediate stages to the central data facility. For this purpose it is necessary to employ one or more transmission technologies. Some of these technologies are quite standard; wire, RF, and optical (IR) are some high-level examples. Some sub-categories might include the telephone or a cell phone. But the optical bar code scanner is as much a device for interrogating an identification marking on an object as is the RF interrogator for use with an RFID tag, or the IR interrogator for use with an IRID tag. And in that sense, they are communication devices as well.

The usability of various communication devices and technologies must be judged in terms of their reliability, security, and risk of RFI. In this context, reliability refers to the likelihood that the device or technology will be able to perform its functions under abnormal operating conditions. What happens when the bar code on vehicle A is covered with mud or someone's coat, or has simply fallen off? Security is concerned with the susceptibility of the data transmissions to interception, denial, or corruption. The RFI risk is concerned with whether transmissions from the device are likely to interfere with those to or from another (not necessarily AIT) device.

Some of the technologies uncovered in our search include capabilities not only to identify, locate, and query the state of an object, but also to communicate information to the object. This additional capability seems most appropriate for personnel objects, for providing brief messages for alerting, warning, or instructing. But one can also imagine cases where it might be desirable to send information to other types of objects. If, for example, a state sensor detected that the fuel in a vehicle or storage facility was contaminated in some way, it would be possible to communicate that fact to an alerting (warning) device on the vehicle or storage facility. RFID technologies our search identified possess some of these capabilities. A type of pager device is one tool for communicating with a person. It is a small step from communicating with a person to communicating a change in state of an inanimate object.

9.6 Specific Architectures

The survey identified only a few complete architectures for asset tracking. The most notable are a vehicle tracking system for use with a bus line and a centralized world-wide asset tracking system based on the Internet. Architecture, for our purposes, is a complete AIT package for a class of objects with sufficiently similar requirements. The architecture includes identification, location, state, transmission, and communication (if appropriate) technologies, connected in a fashion consistent with operational needs as well as the needs and limitations of the specific component technologies.

The best choice of AIT architecture for use with a class of objects at a given local, operational level will ordinarily depend upon a consideration of the AIT requirements for all classes of objects at that level, the wing level, for example. That is, it should be expected that the apparent best monitoring choice for a class of objects viewed in isolation would not be the best choice when viewed in the context of the complete, local monitoring requirement. There may be a synergism wherein costly facilities acquired for high-value assets may have excess capability that

may be effectively applied to monitoring lower-value assets. No such cases have yet been identified, but this possibility should not be ignored.

9.7 Recommendations for Further Study

9.7.1 Personnel Tracking

The ParkWatch, Inc. RFID system of tracking individuals or equipment in a relatively large geographical area (<http://www.parkwatch.com/>) is a promising system and still in a growth phase. Their system is being successfully used to track individuals and groups of people in a 65-acre theme park with only 12 antennas. ParkWatch, Inc. was actively seeking new installation sites at the Frontline Solutions Chicago 2000 Expo, 3-5 October 2000. AFRL may be able to interest ParkWatch, Inc. in demonstrating its system at a typical squadron or wing generation, mobility, or employment exercise.

9.7.2 Speech/Speaker Recognition

The AFRL should take advantage of the ongoing Lawrence Livermore National Laboratory (<http://speech.llnl.gov/>) speech recognition research. Since they welcome joint research, it might be possible to further explore the use of voice commands to and from central databases across hand-held units to gain information and request additional data.

9.7.3 Optical Memory Card

This is not a passive system but is worthy of further investigation; not all AIT requirements have a passive solution. LaserCard Systems Corporation's web site at <http://www.lasercard.com/> contains a wealth of information about how such a system is already being used. For \$2,200 plus shipping and handling, they will provide a development kit as described below. This would be an inexpensive way to get a technology demonstrator for keeping a mobile database of object history, including maintenance actions, personnel actions (such as training events, medical information, certifications, etc.) and shipping information. The LaserCard® Development Kit* contains the following items:

- 100 Optical Memory Cards
- Optical Card Drive**
- Adaptec AVA-1505 SCSI Board and Cable
- Developer's Toolkit CD containing:
 - ◆ LCFS 32-bit DLL and Active X-DLL
 - ◆ Windows NT driver and API
 - ◆ Card Filer GUI utility
 - ◆ Drive Diagnostic Program

* This is a promotional product. Orders beyond one per application developer are subject to approval.

** All optical card drives supplied in development kits are refurbished units with a six-month warranty.

Appendix A - References

The following documents were reviewed while researching this project.

- Magazines

- ◆ Cleveland, Robert F., Jr. and Jerry L. Ulcek. "Questions and Answers about Biological Effects and Potential Hazards of Radio Frequency Electromagnetic Fields." *OET Bulletin 56, 4th Ed.* Washington, DC: Office of Engineering and Technology, Federal Communications Commission, Aug. 1999.
- ◆ Conley, Jim. "A Second Chance for Universal ID Cards." *Smart Business Magazine* July 2000.
- ◆ Earle, M. D. "Characteristics of Infrared Radiation." *Electronic Countermeasures*. Ed. J. A. Boyd et al. Los Altos Hills, CA: Peninsula Publishing (1978). Declassified republication of a classified textbook of the same title published circa 1961. Earle further references S. S. Ballard, L. Larmore, and S. Passman, "Fundamentals of Infrared for Military Applications," RAND Report R-297, 31 Mar. 1956 [CONFIDENTIAL]
- ◆ Foster, K. R. & Moulder, J. E. "Are Mobile Phones Safe?" *IEEE Spectrum* 37:8 (2000).
- ◆ Geier, Jim. "New Standards, Lower Prices Foster RFID Growth." *idSYSTEMS* Oct. 2000.
- ◆ Kocks, Kathleen. "Cellular Intercept: Not Getting Any Easier." *Journal of Electronic Defense*. 23:8 (2000).
- ◆ Langberg, Mike. "Tech Talk From Silicon Valley." *Small Business Computing* Aug. 2000.
- ◆ Masquelier, Barbara. "Logistics Control and Information Support." *Air Force Journal of Logistics*, XXIV:1 (Spring 2000).
- ◆ Mays, Robin, Capt. "Mobility Magic, Air Commando 'Smart Card' Speeds Deployment, Boosts Accountability," *USAF Logistics Officer Association* Spring 2000.
- ◆ "Personal Physiological Monitors Find Warfighter-Effectiveness Edge," *SIGNAL* Aug. 2000.
- ◆ Shawlee, Walter, II. "Flight-Following Via E-Mail." *Avionic* Oct. 2000.
- ◆ Strohmeyer, Robert. "Flexible Circuits, Roll out the Next Generation of Hardware. (Literally)." *Smart Business Magazine* July 2000.
- ◆ "Watch This: Six Things You'll Want to Strap on Your Body. No, Really." *Smart Business* June 2000.
- ◆ "Wearable Computers." *Avionics* Oct. 2000.

- ♦ White, Ron. "Electronic Toll Collection, How It Works." *Smart Business Magazine* June 2000.
- Books
 - ♦ *Reference Data for Radio Engineers, 6th Ed.* Indianapolis: Howard W. Sams & Co. Inc. 2000.
 - ♦ Schleher, D. Curtis. *Introduction to Electronic Warfare*. Dedham, MA. Artech House, Inc. 2000.
 - ♦ Terman, F. E., et al. *Electronic and Radio Engineering, 4th Ed.* New York: McGraw-Hill. 1955.
- Newspapers
 - ♦ "Army's new password: 'Biometrics.'" *USA Today* 22 June 2000.
- LOCIS documents
 - ♦ "Architecture & Systems Suitability Technical Paper for Logistics Control and Information Support (LOCIS), Final." 3 Apr. 1997.
 - ♦ "Concept of Operations (CONOPS) Version 12.0 for Logistics Control and Information Support (LOCIS)", U.S. Air Force Research Laboratory, Logistics Readiness Branch." 21 Dec. 1999.
 - ♦ "Data Requirements Technical Paper for Logistics Control and Information Support (LOCIS), Final." 4 Apr. 1997.
 - ♦ "Enabling Technology Technical Paper for Logistics Control and Information Support (LOCIS), Final." 3 Apr. 1997.
 - ♦ "Logistics Command and Control Information Support (LOCIS) Strategic Planning, Requirement Identification Phase." 11 Dec. 1995.
 - ♦ "Logistics Control and Information Support Phase III (LOCIS III), Concept of Operations Demonstration Development, Final Report." Oct. 1997.
 - ♦ "Logistics Control and Information Support Phase III (LOCIS III), Critical Logistics Information and Data Element Mapping, Final Report." June 1997.
 - ♦ "Logistics Control and Information Support Phase III (LOCIS III), Decision Algorithms for Direct Sortie Generation Activities, 2nd Final Report." Oct. 1997.
 - ♦ "Logistics Control and Information Support Phase III (LOCIS III), Final Report, Preliminary Final." Oct. 1997.
 - ♦ "Logistics Control and Information Support Phase III (LOCIS III), Hardware/Software Architecture and System Design, 2nd Final Report." Sept. 1997.

- ◆ "Logistics Control and Information Support Phase III (LOCIS III), Technical Concept Demonstration (TCD), Final Report." Oct. 1997.
- ◆ "Recommended Methods and Functional Economic Analysis Technical Paper for Logistics Control and Information Support (LOCIS), Final." 4 Apr. 1997.
- ◆ "Specific Functions Technical Paper for Logistics Control and Information Support (LOCIS), Final." 14 Feb. 1997.
- ◆ "Technology Demonstrator for Logistics Control and Information Support (LOCIS), Final." 2 Apr. 1997.
- DoD, USAF and Army Concept Papers and Briefings
 - ◆ "Air Force 2025 Final Report." Air University, U.S. Air Force, June 1996.
 - ◆ "AIT Implementation in USTRANSCOM." Update to Principals Briefing, United States Transportation Command, 15 Jan. 1999.
 - ◆ "Army Vision 2010, Focused Logistics." U.S. Army, Nov. 1996.
 - ◆ "DoD Implementation Plan for Logistics Automatic Identification Technology." AIT Task Force Deputy Under Secretary of Defense for Logistics (DUSD[L]), Mar. 2000.
 - ◆ "DoD Logistics Strategic Plan," Deputy Under Secretary of Defense (Logistics), Aug. 1999.
 - ◆ "JointVision 2010" and "JointVision 2020," Chairman of the Joint Chiefs of Staff, 5126 Joint Staff, Pentagon, Washington, D.C. 20318-5126.
 - ◆ "Logistics Automatic Identification Technology Concept of Operations", AIT Task Force Deputy Under Secretary of Defense for Logistics (DUSD[L]), Nov. 1997.
 - ◆ "United States Air Force (USAF) Agile Combat Support (ACS) Concept of Operations (CONOPS)." USAF/ILXX.
- Miscellaneous
 - ◆ Arthur D. Little, Inc. "Wireless Sensor Review Interim Report"(TRS DO13). Presentation to AFRL, 17 Aug. 2000.
 - ◆ Bhatti, Saleem. *The Electromagnetic Spectrum: Propagation in Free-Space and the Atmosphere: Noise in Free Space*. 1995. U College London. 23 May 2000
<<<http://www-dept.cs.ucl.ac.uk/staff/S.Bhatti/D51-notes/node22.html>>>
 - ◆ Brookfield, WI: RF TECHNOLOGIES, INC. Undated.
 - ◆ Eagleson, Jim. "RF/ID: Spectrum & Applications." (Unpublished briefing)

- ◆ “Evaluation of AIT Operational Prototype.” Executive Summary and Appendix G – AIT Equipment. SRA 31 Mar. 1999.
- ◆ Milshteyn, Aleks and Pete Staples. “Resource for Frequency Allocations and Related Information.” 30 May 2000. SuperFreq. 23 July 2000 <<www.superfreq.com>>.
- ◆ “Scientist Says Cell Phones Dangerous for Children.” London: Reuters, 25 Nov. 2000.
- ◆ Sticht, D. *Electronic Warfare and Radar Systems Engineering Handbook*. Naval Air Warfare Center Weapons Division. 15 Oct. 2000.
<<<http://ewhdbks.mugu.navy.mil/home.htm>>>.
- Automated Identification for Logistics Control Web Sites

These World Wide Web site locations are considered most interesting for readers of this report. The sites contain additional information that is too voluminous to repeat. Many of the sites also list additional information sources that would be useful for further study.

AIM (global trade association of AIT developers, solutions, etc)
<http://www.aimglobal.org/>

Air Force AIT PMO Home Page
<http://www.afmc-pub.wpafb.af.mil/HQ-AFMC/LG/LSO/LOA/>

AutoID.Org, Inc (resource for auto ID technical information on the web)
<http://www.autoid.org/>

Auto Image ID, Inc (2D bar code information)
http://www.autoimageid.com/html/2d_codes.htm

Biometrics Consortium (U.S. Government's focal point for research, development, test, evaluation, and application of biometrics-based personal identification/verification technology)
<http://www.biometrics.org/>

Biometrics Digest (all you ever wanted to know about biometrics)
<http://webusers.anet-stl.com/~wrogers/biometrics/>

The Center for AutoID at Ohio University (academic and research)
<http://webit.ent.ohiou.edu/autoid/index.html>

Chairman, Joint Chiefs of Staff: Joint Vision 2010
<http://www.dtic.mil/jv2010/jvpub.htm>

Chairman, Joint Chiefs of Staff: Joint Vision 2020
<http://www.dtic.mil/jv2020/>

Command Technology, Inc (click on "The Future" to read about wearable computers for aircraft maintenance information)

<http://www.c2aircraft.com/>

Datastrip Products Inc, (smart card technology information)

<http://www.datastrip.com/prod-2D.htm>

DataTrac Systems (aircraft position tracking and reporting)

<http://www.datatrac.ca>

DoD AIT Applications for Maintenance Site [ADUSD(L)/MPP&R]

<http://www.acq.osd.mil/log/mp/ait/ait.html>

DoD AIT Task Force

<http://www.dodait.com/>

Dynasys Technologies Inc. (auto ID products)

<http://www.dyna-sys.com>

Escort Memory Systems (RFID solutions provider)

<http://www.ems-rfid.com/>

Ethentica, Incorporated (fingerprint authentication products)

<http://www.ethentica.com>

Frontline Solutions Web Site (general information)

<http://www.frontlinemagazine.com/>

HID Corporation Home Page (RFID, smart card, biometrics)

<http://www.hidcorp.com/>

Identix, Incorporated (fingerprint recognition systems)

<http://www.identix.com/>

IDSYSTEMS' Newsletter and IDSystems.com Home Page (general information)

<http://www.idsystems.com/>

Intermec Corp Home Page (AIT product development)

<http://corp.intermec.com/>

Iridian Technologies (iris recognition)

<http://www.iriscan.com/main.html>

Jim Eagleson's Personal RFID Information Web Site (links to information)

http://personal.pacalink.net/~jimeagle/rfid_mfg.htm

LaserCard Systems (optical memory card information)

<http://www.lasercard.com/>

Lawrence Livermore National Laboratory (high-level research)

<http://www.llnl.gov/>

Lawrence Livermore National Laboratory (speech research web site)
<http://speech.llnl.gov/>

Melard Technologies (rugged, wireless computer systems/LANs)
<http://www.melard.com>

Other AIT Internet Links (a plethora of AIT web sites)
<http://www.afmc.wpafb.af.mil/HQ-AFMC/LG/LSO/LOA/other.htm>

ParkWatch, Inc (personnel locator system)
<http://www.parkwatch.com/>

Pennsylvania State University Engineering Research (academic and research)
<http://www.engr.psu.edu>

PinPoint Corporation (RTLS and mobile resource management system)
<http://www.pinpointco.com/>

QED Systems (glossary of AIT terms)
<http://www.qed.org/glossary.htm>

Randall's and Clara's Web Site (RFID info)
<http://home.att.net/~randall.j.jackson/home.htm>

RF Code, Inc. (RTLS)
<http://www.rfcode.com>

Russ Adams' Page on Bar Codes
<http://www.adams1.com/pub/russadam/stack.html>

Savi Technology Home Page (worldwide Internet-based supply chain asset tracking)
<http://www.savi.com/>

SIGNAL Magazine's Home Page (general information)
<http://www.us.net/signal/index.html>

The Smart Card Resource Center (numerous links to solution providers, vendors, etc.)
<http://www.smart-card.com/>

Symbol Technologies, Inc (equipment and integration services, also information about a U.S. Government DoD Contract)
<http://www.symbol.com/>

System Resources Corporation, Defense Systems (click on "Navigate" for services and solutions)
<http://www.srcorp.com/defense.html>

Texas Instruments (RFID smart tags)
<http://www.ti.com/tiris/default.htm>

TransCore, Amtec Systems (RFID solutions provider)
<http://www.amtech.com/>

TSS-RFID Traffic Supervision Systems (vehicle location and status system)
<http://www.tss-tag.com/>

USAF Agile Combat Support CONOPS Page, HQ USAF/ILXX
<http://www.il.hq.af.mil/ilx/ilxx/acs/index.html>

U.S. Army Functional Requirements of Force XXI Digitized Battle Command
http://call.army.mil/call/ctc_bull/95-11/ctc4.htm

U.S. Army Home Page
<http://www.army.mil/>

U.S. Army Vision
<http://www.army.mil/armyvision/default.htm>

U.S. Army Vision 2010 Focused Logistics
http://www.army.mil/2010/focused_logistics.htm

U.S. Navy AIT Web Site (very good description of types of AIT, initiatives, & glossary)
<http://www.navy-ait.com/>

Versus Technology Home Page (personnel and equipment locating system)
<http://www.versustech.com/index.html>

Versus Technology Press Releases
<http://biz.yahoo.com/n/v/vsti.ob.html>

Welcome to AF2025 (USAF Chief of Staff study led by Air University)
<http://www.au.af.mil/au/2025/>

WhereNet Corporation (global visibility RTLS)
<http://www.wherenet.com/homefr.htm>

Worth Data, USA (bar code and RF transmitter pricing)
<http://www.barcodehq.com/>

Appendix B – ISO/IEC JTC 1/SC 31 Information Technology, Automatic Identification and Data Capture Techniques — Vocabulary

Pursuant to Resolution 25 of the 11-13 April 2000 Plenary of ISO/IEC JTC 1/SC 31 in Tokyo, Japan, the Vocabulary Rapporteur prepared this document for approval. It is an internationally recognized set of terms and standards to be used when referring to AIT.

The document is maintained at the following web site address:

<http://www.qed.org/glossary/sc31orm.html>



ISO/IEC JTC 1/SC 31 INFORMATION TECHNOLOGY, AUTOMATIC IDENTIFICATION
AND DATA CAPTURE TECHNIQUES — VOCABULARY

DATE: 2000-07-01

DOC TYPE: Report

TITLE Report of the JTC 1/SC 31 Vocabulary Rapporteur

SOURCE Craig K. Harmon, ISO/IEC JTC 1/SC 31 Vocabulary Rapporteur

STATUS For Consideration by the Members of ISO/IEC JTC 1/SC 31

ACTION For information, comment, and approval

DISTRIBUTION ISO/IEC JTC 1/SC 31 secretariat and JTC 1/SC 31 members

MEDIUM Email

NO. OF PAGES 23

Foreword

The *Proposed modifications to the terms and definitions currently contained in the ISO/IEC JTC1/SC 31 harmonized vocabulary (EN 1556)* was circulated for Letter Ballot (SC 31 N0614) on 27 December 1999. At the close of the comment period on 2 February 2000 seven members and one member in liaison had commented on the Ballot though all members voting approved the document (SC 31 N0637). The comments received were identical. On 27 March 2000, the Vocabulary Rapporteur sent the comments received to all Member National Bodies requesting approval of the changes based on the comments received. All responding members approved the changes. Pursuant to Resolution 25 of the 11-13 April 2000 Plenary of ISO/IEC JTC 1/SC 31 in Tokyo, Japan, the Vocabulary Rapporteur prepared this document for national body approval.

Document changes since last are noted in the Change Record Summary on the following page.

This document is maintained at the following web site address:
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The Vocabulary Rapporteur herein resubmits this report to National Bodies for comment.

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Change Record Summary

Date	Change
10-06-1999	"add-on symbol" added per Work Group request
10-06-1999	"alignment pattern" added per Work Group request
10-06-1999	"aperture" changed per Work Group request
10-06-1999	"auxiliary character" modified / "auxiliary pattern" not included on VR recommendation
10-06-1999	"bar" changed per Work Group request
10-06-1999	"bar-space pattern" added per Work Group request
10-06-1999	"bar width adjustment" added per Work Group request
10-06-1999	"bar width compensation" added per Work Group request
10-06-1999	"bar width increase" added per Work Group request
10-06-1999	"bar width reduction" added per Work Group request
10-06-1999	"bar width reduction/increase" omitted on VR recommendation
10-06-1999	"Basic Channel Model" added per Work Group request
10-06-1999	"compaction mode" added per Work Group request
10-06-1999	"contact scanner" added per Work Group request
10-06-1999	"decodability" added per Work Group request
10-06-1999	"decode" added per Work Group request
10-06-1999	"defect" added per Work Group request
10-06-1999	"delineator" added per Work Group request
10-06-1999	"distortion" added per Work Group request
10-06-1999	"ECI designator" added per Work Group request
10-06-1999	"encoding" added per Work Group request
10-06-1999	"error correction codeword" added per Work Group request
10-06-1999	"even parity" added per Work Group request
10-06-1999	"Extended Channel Interpretation" added per Work Group request
10-06-1999	"Extended Channel Model" added per Work Group request
10-06-1999	"gloss" added per Work Group request
10-06-1999	"guard pattern" added per Work Group request
10-06-1999	"(n,k) symbology" changed per Work Group request
10-06-1999	"odd parity" added per Work Group request
10-06-1999	"raster" added per Work Group request
10-06-1999	"read rate" added per Work Group request
10-06-1999	"reference decode algorithm" changed per Work Group request
10-06-1999	"reference threshold" changed per Work Group request
10-06-1999	"resolution" changed per Work Group request and VR recommendation
10-06-1999	"scan" added per Work Group request
10-06-1999	"show through" changed per Work Group request
10-06-1999	"symbol contrast" changed per Work Group request
10-06-1999	"vertical redundancy" added per Work Group request
10-06-1999	Abbreviations & Symbols added per VR recommendation
06-28-2000	"numbering organization" changed to "EAN numbering organization"
06-28-2000	"number set" changed to "EAN/UPC number set"
06-28-2000	"UCC/EAN system" changed to "EAN.UCC system"

Contents

	Page
Foreword	2
Change record	3
Definitions of terms	5
Abbreviations	24
Symbols	25
Annex A (informative) Maintenance	26

Definitions of Terms

add-on symbol:

A symbol used to encode information supplementary to that in the main symbol.

algorithm

A set of steps to be taken to effect a desired calculation.

alphanumeric

Alphabetic and numeric including punctuation marks.

alignment pattern

A fixed reference pattern in defined positions in a matrix symbology, which enables the decode software to re-synchronize the coordinate mapping of the image modules in the event of moderate amounts of distortion of the image.

aperture

The effective opening in an optical system that establishes the field of view.

application standard

Specification defining the method by which and conditions under which bar code technology may be applied to a particular purpose, prescribing, for example, data formats, optical requirements and symbology-related parameters as subsets of the range defined by relevant technical standards.

ASCII

American Standard Code for Information Interchange: a computer code, as described in ISO 646, consisting of 128 alphanumeric and control characters, each encoded with 7 bits (8 including parity check), used for the exchange of information between computerized systems.

autodiscrimination

The ability of a bar code reader to distinguish automatically between two or more symbologies.

auxiliary character/pattern

A non-data character - e.g. start character, stop character, center pattern, delineator pattern, latch character, mode indicator, shift character, code subset change characters, and function characters. See Overhead.

background

The light area between and surrounding the dark elements of a printed symbol. The background can be the substrate on which the symbol is printed or an over-printing of a suitable light color.

bar

A dark element corresponding to a region of a scan reflectance profile below the global threshold.

bar code

An array of parallel rectangular bars and spaces arranged according to the encodation rules of a particular symbol specification in order to represent data in machine-readable form.

bar code character

See Symbol Character.

bar code density (symbol density)

The number of characters that can be represented in a bar code symbol per unit of measure, usually expressed as characters per inch (cpi) or per centimeter for linear bar codes and per square inch or per square centimeter for multi-row symbologies. The width of the narrowest bar or space, the wide to narrow ratio, the number of bars and spaces per character and the width of the intercharacter gap, if any, are the controlling factors.

bar code master

The original film or other image of a bar code symbol, produced to close tolerances and intended for reproduction by conventional printing processes (e.g. for incorporation in a printed packaging design).

bar code reader

A device used to capture the data encoded in a bar code symbol. It consists of two parts: a) the scanner, an input device which sends signals proportional to the reflectivity of each successive element of the symbol to the decoder, and b) the decoder, which examines the signals from the scanner and translates them into recognizable or computer-compatible data. The decoder itself is sometimes erroneously called a reader.

bar code symbol

The combination of symbol characters and features required by a particular symbology, including quiet zones, start and stop characters, data characters, check characters and other auxiliary patterns, which together form a complete scannable entity.

bar height

The dimension of the individual bars in a linear bar code symbol or in a row of a multi-row bar code symbol, measured perpendicular to the scanning direction. See also Y dimension.

bar-space sequence

The sequence which represents the module widths of the elements of a symbol character.

bar width

The transverse dimension of an individual bar in a bar code symbol, measured parallel to the scanning direction. The number of possible width variations within a particular printed symbol depends on the symbology used.

bar width adjustment (BWA)

The amount of decrease (bar width reduction) or increase (bar width increase) by which the bars of a bar code master are adjusted, to compensate respectively for gain or loss of bar widths during reprographic and printing processes.

bar width compensation (BWC)

The extent by which the widths of the bars in a bar code master or in a digital bar code file, is reduced/increased in order to correct for expected print or image gain/loss.

bar width gain/loss

See Print Gain/Loss.

bar width increase
See bar width adjustment.

bar width reduction
See bar width adjustment.

Basic Channel Model

A standard system for encoding and transmitting bar code data where data message bytes are output from the decoder but no control information about the message is transmitted. A decoder, complying to this model, operates in Basic Channel Mode.

bearer bar

A bar abutting the tops and bottoms of the bars in a bar code symbol, or a frame surrounding the entire symbol, intended to equalize the pressure exerted by the printing plate over the entire surface of the symbol, and/or to prevent a short scan by the bar code reader.

bi-directional

In two directions - viz. backwards and forwards. Denoting that a bar code symbol can be read successfully either backwards or forwards. Denoting a scanner that can operate successfully either backward or forwards.

binary

Denoting a numbering system to base 2 in which numbers are expressed as combinations of the digits 0 and 1, with positional weighting based on powers of 2. In computing these can be represented electrically by 'off' and 'on' respectively, or in bar codes by narrow and wide elements or by the absence or presence of a bar module.

binary coded decimal (BCD)

A method of representing decimal numbers in binary code as groups of four bits, with weighting values 8, 4, 2, 1 reading from left to right, each group representing one decimal digit, for example 0010 0011 for 23.

binary symbology

See Two-Width Symbology.

bit

Abbreviation for binary digit. 1. A single element (0 or 1) in a binary number. 2. A unit of information capacity in a binary storage device.

CCD (charge-coupled device)

An electronic light-sensitive component used in a linear or two-dimensional array as the light-collecting element in certain types of bar code reader.

character

See Character Set, Data Character, Symbol Character, Human Readable Character.

character set

The total range of letters, numbers, and symbols that can be encoded in a particular symbology. See Code Page, Code Set.

check digit/character

A digit or character calculated from other characters in a code by means of a defined algorithm and used to check that the code is correctly composed. See Symbol Check Character, Data Check Character/Digit.

clear area

See Quiet Zone.

closed application environment (system)

An application which is intended for use by a closed group of users, typically within a single organization or subject to a specific agreement. Compare Open Application Environment.

closed system

See Closed Application Environment.

code page

A table showing the character allocated to each byte value in a coded character set.

code set

A subset of the character set of a particular symbology. See Character Set.

coded character set

A set of unambiguous rules establishing a character set and the relationship between the characters of the set and their byte values.

codeword

A symbol character value. An intermediate level of coding between source data and the graphical encodation in a symbol.

column

The horizontal symbol character position in a row of a multi-row symbology.

compaction mode

The name given to one of three data compaction algorithms in PDF417: Text, Numeric and Byte Compaction modes. These modes efficiently map 8-bit data bytes into PDF417 codewords.

contact scanner

A particular type of scanner in which the scanning action takes place with the scanner in actual or near contact with the symbol. E.g. wand or light pen.

concatenation

The linking or chaining together (1) of separate items of data in a bar code symbol, or (2) of the data contained in two or more separate bar code symbols (also referred to as "message append" and "structured append").

continuous code

A symbology in which there is no intercharacter gap, i.e. the final element of one symbol character abuts the first element of the next symbol character and all the elements carry data contiguously. Compare Discrete Code.

conventional printing process

One of the printing processes typically using a printing plate (or cylinder) and wet ink to produce multiple impressions of an image on a substrate. Includes lithography, letterpress, flexography, photogravure, screen process, hot foil stamping. Compare On-Demand Printing.

corner marks

Marks which indicate the four corners of a bar code symbol including the light margins on a bar code master. Corner marks are not normally printed.

CPI (characters per inch)

Used as a measure of bar code density.

data character

A single numeric digit, alphabetic character or punctuation mark, or control character, which represents information. Compare Symbol Character.

data check character/digit

A digit or character calculated from data and appended as part of the data string to ensure that the data is correctly composed and transmitted. Compare Symbol Check Character.

data codeword

A codeword which encodes data according to one of the compaction schemes of a symbology.

data compaction (or data compaction scheme)

A mechanism or algorithm to process the original data so that it is represented efficiently in as few codewords as possible in a symbology.

data region

That part of a symbol used to encode data codewords as opposed to other symbol overhead.

data separator character

An auxiliary character used to determine the end of one and the beginning of the next of two items of data, which have been concatenated.

decodability

Measurement of relations from combinations of bars and spaces together or alone according the reference decode algorithm. The value gives a measurement of how good a barcode symbol can be decoded.

decode

Determination of the information encoded in a bar code symbol.

decode algorithm

The set of rules used, in a bar code or matrix symbology, to convert the element pattern of a symbol to data characters.

decoder

An electronic assembly which translates the proportional electrical signals from a scanner into recognizable or computer-compatible data.

defect

Area of unwanted image, usually referred to as spots or voids.

delineator

An auxiliary pattern used to separate characters within an add-on symbol.

densitometer

An instrument that measures the degree to which light is transmitted through or reflected from a material. A calibrated photometer compares the transmitted or reflective light with the incident light, and the result may be displayed as percentage reflectance or density.

density (optical)

Measure of the relationship between transmitted or reflected light and the incident light, expressed as the logarithms of their ratio:

Optical density = $\text{Log}_{10} (I/T)$,

where I = Incident light

T = Transmitted or reflected light.

depth of field

The range of distances over which a scanner can reliably read a symbol of given characteristics. Equal to the range of the scanner minus its optical throw. See Optical Throw, Range, Reading Distance.

diffuse reflection

Reflection of light in all directions. Non-glossy surfaces reflect light in this way, whereas glossy surfaces produce specular reflection.

digital

Represented in a binary form rather than a continuously varying analogue form. In the context of integrated artwork, produced by a number of discrete dots rather than a continuous image.

discrete code

A symbology in which the spaces between symbol characters (intercharacter gaps) do not contain information as each character begins and ends with a bar. Compare Continuous Code.

disproportioning

See *distortion*

distortion

The process by which the height to width ratio of a piece of artwork is changed, to compensate for the dimensional change which is introduced to an image, when a flexible, relief printing plate is wrapped around the print cylinder of a rotary printing press.

dot code

A subset of matrix symbologies in which individual modules are surrounded by clear space which has no information content.

EAN

Abbreviation for EAN International. Also used to refer to the bar code symbology used for marking of consumer products in accordance with this body's specifications.

EAN.UCC System

A system for the unique numbering and identification of products, handling units, assets, locations, and services according to a set of rules maintained by EAN International and the Uniform Code Council.

EAN/UPC number set

A series of ten bar/space patterns of either even or odd parity encoding the digits 0 to 9.

EAN numbering organization

An agency responsible for the administration of the UCC/EAN system and maintenance of a number bank within a defined territory.

ECI designator

A six-digit number identifying a specific ECI assignment.

effective aperture

The apparent field of view of a scanner or similar device determined by the smaller of the spot size and the physical aperture of the scanner for reception of reflected light.

element

A single bar or space in a bar code symbol. The width of individual elements may be expressed in modules, or in multiples of the X dimension.

encode

Put into the form of a code.

encoding

Conversion of data into the form of a symbol.

erasure

A type of error represented by a physically missing character, or a symbol character that has failed to be decoded, as opposed to a substitution error or misdecode.

error correction

A mathematical procedure which allows the detection and rectification of errors to take place.

error correction codeword

A codeword in a symbol which encodes a value derived from the error correction codeword algorithm to enable decode errors to be detected and, depending on the error correction level, to be corrected.

error correction level

The degree of error correction capability in a symbology, where this is not fixed but subject to some user choice.

even parity

A characteristic of the encodation of a symbol character whereby the character contains an even number of dark modules.

extended ASCII

An extended code set encoded in 8 bits giving values from 0 to 255 in accordance with ISO 8859.

Extended Channel Interpretation (ECI)

A protocol used by some symbologies that allows the output data stream to have interpretations other than that of the default character set.

Extended Channel Model

A system for encoding and transmitting both data message bytes and control information about the message. A decoder, complying with this model, operates in Extended Channel Mode. The control information is communicated using Extended Channel Interpretation (ECI) escape sequences.

eye-readable character

See Human-readable Character.

field of view

The length of bar code that can be read in one scan. For wand scanners and others where the scanner beam has to be manually moved across the symbol, field of view is a function of the operator's ability to scan smoothly.

filler character

A character inserted to extend an item of data to achieve a desired length. (Also Pad Character.)

film master

A bar code master on film.

finder pattern

A unique pattern in a symbology used to locate symbols conforming with the symbology rules within a field of view.

fixed beam scanner

A scanning device in which the beam of light is emitted in a fixed direction, relying on movement of the bar code symbol relative to the beam to achieve the scanning action.

fixed parity

A bar code symbol or a defined section of a symbol has fixed parity if every symbol character has the same parity (either even or odd).

flat-bed scanner

An omnidirectional scanner in which the scanning beam(s) are directed upwards through a window or slot(s) and over which the bar code symbol is passed.

font

A set of characters of a specific style and size of graphic type. Also used analogously to refer to the set of bar code symbol characters for a symbology in on-demand printing equipment.

gloss

The propensity of a surface to reflect a proportion of incident light in a specular manner.

guard pattern

An auxiliary pattern of bars/spaces corresponding to start or stop patterns in other symbologies, or serving to separate the two halves of a symbol.

helium neon laser (He Ne laser)

A type of laser commonly used in bar code scanners. It emits visible coherent red light at a wavelength of 632,8 nm.

human readable character

The representation of a bar code data character or data check character in a standard eye-readable alphabet or numerals, as distinct from its machine-readable representation.

integrated artwork

Artwork in which the bar code symbol and the other graphics are generated together by electronic means.

intercharacter gap

The space between the last bar of one symbol character and the first bar of the next in a discrete bar code symbology. See Discrete Code, Continuous Code.

label printing machine

In the context of these standards a device for producing bar code labels directly from data.

ladder orientation

Position of a bar code symbol in which the axis of the bars is horizontal in order to enable a vertical scanning beam to traverse the complete symbol. Compare Picket Fence Orientation.

LASER (Light Amplification by the Stimulated Emission of Radiation)

A device for producing an intense beam of monochromatic coherent light.

laser diode

A laser device using a solid-state component as the light source.

laser engraver

A device that uses concentrated heat from a laser beam to engrave graphic images directly on to an item to be marked.

laser scanner

A device for scanning bar codes which uses a laser beam as its light source.

latch character

A symbology character that is used to switch from one code set to another. The code set stays in effect until another latch or shift character is explicitly brought into use or until the end of the symbol is reached.

leading zeros

Zeros at the left of a number.

LED (light emitting diode)

A semiconductor that produces light at a wavelength determined by its chemical composition as a result of electrical stimulation. A range of devices is available, each having an output with a peak

wavelength in the spectrum between 600 nm (visible red) and 900 nm (infrared). It is commonly used as a light source in wand, CCD and slot-type bar code readers.

license plate

A unique number, irrespective of its use, specified by the issuer of a label (or similar item) and applied to an entity to provide for traceability, regardless of product, its destination and valid for its lifetime.

light margin

See Quiet Zone.

light pen (light wand)

A hand-held bar code reading device that must be passed across the symbol in order to decode it.

linear symbology

A bar code symbology in which the symbol is formed of a single row of symbol characters.

Compare Multi-Row Symbology.

magnification factor

The constant multiplier applied to the nominal dimensions of a bar code symbol to obtain the actual dimensions at which it must be produced.

matrix symbology

A collection of polygonal or circular elements in a regular pattern to represent data for retrieval by a vision scanning system.

message append

See Structured Append

misread (bad read, mis-scan)

A disparity between the data encoded in a bar code symbol and the data output from a bar code reader. The error will not be detected by test routines in the decode algorithm. The output data may erroneously correspond with valid data. Compare Non-read.

modular symbology

A bar code symbology in which symbol characters are composed of elements the nominal widths of which are integer multiples of the X dimension or module width. See Module, (n,k) Symbology.

module

1. In a linear or multi-row bar code symbology the nominal unit of measure in a symbol character. In certain symbologies, element widths may be specified as multiples of one module. Equivalent to X Dimension.

2. In a matrix symbology, a single cell or element used to encode one bit of the codeword.

modulo

Usually used in the form Modulo-10, Modulo-103 etc. The type of algorithm used to calculate the check character for certain bar code symbols.

moving beam scanner

A scanning device in which the scanning beam is swept by mechanical or electronic means.

multi-row symbology (also stacked symbology)

A bar code symbology in which the symbol consists of two or more vertically adjacent rows of symbol characters. Compare Linear Symbology.

nanometer

A unit of measure used to define the wavelength (and hence color) of light. One nanometer is one thousand millionth of a meter (10^{-9} meters), or ten Ångströms. Abbreviation: nm.

(n,k) symbology

A class of bar code symbologies in which each symbol character is n modules in width and is composed of k bar and space pairs.

nominal

Denoting the 'standard' or 'ideal' values of specified parameters of the elements that make up the characters of symbols.

non-read (no-read, non-scan)

Lack of data output when a bar code symbol is scanned due to a defective code, incorrect orientation or speed of scan, scanner failure, or operator error. Compare Misread.

numeric

Denoting a character set that includes only numbers. Compare Alphanumeric.

odd parity

A characteristic of the encodation of a symbol character whereby the character contains an odd number of dark modules.

omnidirectional

In all directions. Used to refer to symbols that can be scanned in any orientation with an appropriate scanner, or to such a scanner.

omnidirectional scanner

A scanner, such as a flat bed scanner, capable of reading symbols whatever their orientation in a plane parallel or near parallel to the exit window of the scanner.

on-demand printing

Printing of bar code symbols and other matter immediately prior to the material being required for application or use, normally using a computer-controlled printer.

opacity

The property of a substance of preventing light from passing through it. Substrate opacity affects show-through from the reverse side of the substrate or any substance underneath it. Ink opacity determines the show through from the substrate.

open application environment (system)

An application in which independent parties may freely participate and in which bilateral arrangements are not necessary. Compare Closed Application Environment.

open system

See Open Application Environment.

optical throw

The distance from the face of a scanning device to the beginning of the depth of field, for a symbol of given characteristics. Compare Depth of Field, Range, Reading Distance.

orientation

Positioning with respect to a specific direction or plane. See Ladder Orientation, Picket Fence Orientation.

orientation pattern

A unique spatial arrangement of dark and light modules in a symbology used to detect the spatial orientation of the symbol.

oscillating mirror scanner

A single beam scanner with an additional mirror oscillating in a plane at right angles to the scanner beam and causing (for example) a horizontal field of view to be swept up and down vertically.

output device

In the context of integrated artwork, the final piece of computer-driven equipment used to produce the artwork, typically an image setter or cylinder engraver.

overhead

The part of a bar code symbol required in addition to the symbol characters encoding data to give the symbol a valid structure. It consists of the auxiliary characters and symbol check characters.

overprinting

Printing on to pre-printed material.

pad character

See Filler Character.

pad codeword

A codeword inserted to extend a codeword sequence to achieve a desired symbol structure, or to fill the capacity of a symbol.

parity

A system for encoding characters as 'odd' (having an odd number of binary ones in their structure) or 'even' (having an even number of binary ones in their structure), used as self-checking mechanism in bar codes. A parity bit (parity bar or module) can be incorporated into an encoded character to make the sum of all the bits always odd or always even, which acts as a fundamental check.

photometer

An instrument used to measure the intensity of light at specified wavelengths. See also Densitometer.

picket fence orientation

Position of a bar code symbol in which the axis of the bars is vertical in order to enable a horizontal scanning beam to traverse the complete symbol. Compare Ladder Orientation.

pitch

Rotation of a bar code symbol about an axis parallel to the height of the bars. Compare Skew, Tilt.

pixel

The smallest image element that when combined with others makes a complete graphic image. (From "picture element")

print contrast signal (PCS)

A measure of the relative difference between the reflectances of light and dark elements (in the following formula, R_L and R_D respectively):

$$PCS = (R_L - R_D) / R_L$$

Compare Reflectance Difference.

print direction

The orientation of the print image as it moves through the print press.

print gain/loss

The increase/decrease in bar width due to effects of the reproduction and printing processes.

print quality

The degree to which a printed optical symbol complies with the requirements which are specified for it, such as dimensions, reflectance, edge roughness, spots, voids, etc., which will affect the performance of the scanner. See Verification.

printability gauge

A series of specially calibrated marks printed on to a substrate to assess or monitor the quality of printing.

printability test

A test of print quality.

quiet zone

The area free from interfering markings which must surround a bar code symbol and, in particular, precede the start character and follow the stop character. Also referred to as light margin or clear area.

range

The maximum distance at which a scanning device can read a symbol of given characteristics. Equal to the sum of optical throw and depth of field. See Depth of Field, Optical Throw, and Reading Distance.

raster

The projection of a laser beam to create multiple, nearly parallel, scan lines instead of a single line.

raster scanner

A moving beam scanner that emits several parallel scanning beams.

reading distance

The distance (or range of distances) from the exit window of a scanner at which the scanner can reliably read a symbol. The minimum reading distance is equal to the optical throw and the maximum reading distance is equal to the range of the scanner. See Depth of Field, Optical Throw, Range.

read rate

The percentage representing the number of good reads per 100 attempts to read a particular symbol.

redundancy

Characteristic whereby information is repeated to increase the probability of its being read or communicated successfully. In a bar code symbol the height of the bars provides vertical redundancy by enabling multiple scan paths to exist through the symbol, only one of which is necessary in theory for a complete decode.

Reed-Solomon error correction code

A linear, error correcting, block code, suited to the correction of character errors that could be, in bar or matrix codes, the obliteration or removal of part of the symbol.

reference decode algorithm

The decode algorithm quoted in a symbology specification as the basis for the reference thresholds, decodability values etc.

reference reflected flux

The radiant power reflected by a magnesium oxide or barium sulphate photometric standard.

reference threshold

The boundary point used by a reference decode algorithm to make a decision as to the measurement of an element or combination of elements.

reflectance

1. The amount of light of a specified wavelength or range of wavelengths that is reflected from a surface. 2. Reflectance (sometimes called reflectance factor). Is measured on a scale of 0 to 1, at a wavelength or bandwidth of light (spectral response) specified in the particular application specification.

$$\text{Reflectance} = R/I$$

where R = reflected light

I = incident light

Barium sulphate or magnesium oxide is used as 'near perfect' reference white standards (a perfect standard of pure white would have a reflectance of 1.00 at any wavelength of light). The absence of any light in a vacuum is used as reference black standard. Samples (such as substrates, inks, etc.) are tested against the standards under similar illumination.

reflectance difference

The difference between the reflectances of light and dark elements of a bar code symbol.

reflectance factor

The ratio of reflected flux to the reference reflected flux.

reflected flux

The radiant power reflected by the sample.

resolution

Measure of the fineness of detail of an image that a piece of equipment can produce or distinguish. The width of the narrowest element capable of being read by the equipment under test.

row

A lateral set of components in a multi-row symbology, comprising a start pattern, a number of symbol characters, and a stop pattern.

scan

(Noun): A single pass of the scanning beam over the symbol or a portion of the symbol, or a single image capture with an image capture device. (Verb): To pass the scanning beam over the symbol or a portion of the symbol, or to capture a single image with an image capture device.

scan reflectance profile

The plot of the variations in reflectance with distance along a scan path through a symbol, representing the analogue waveform produced by a device scanning the symbol.

scan reflectance profile

Plot of variations in reflectance with linear distance along a scan path.

scanner

An electronic device that converts optical information (e.g. a printed bar code) into electrical signals for subsequent decoding and transmission to a computer. See also Bar Code Reader, Decoder.

scanning window

The whole area in front of the exit window of a non-contact scanner in which symbols can be read. Also known as Effective Reading Zone.

self-checking (character self-checking)

A property of a symbology whereby a checking algorithm is applied to each character in the code; substitution errors can then only occur if two or more separate printing defects occur within one character. Codes that are not self-checking usually have a check character added to the encoded data.

shift character

A symbology character which is used to switch from one code set to another for a single character, or in the case of "double shift" or "triple shift" characters, for two or three characters respectively, following which data encodation reverts automatically to the code set from which the shift was invoked.

short read

The reading of an apparently valid shorter symbol within a longer one, of the same or different symbologies.

show through

The property of a substrate that allows underlying markings or materials to affect the reflectance of the substrate. Compare Opacity.

single line (beam) scanner

A scanner in which the light beam traverses a single path, giving a one-dimensional field of view.

skew

Rotation of a bar code symbol about an axis parallel to the symbol width. Compare Pitch, Tilt.

slot reader

A bar code reading device that requires that the bar-coded material is drawn through a slot into which a near-contact bar code reader is built. The device requires that the bar code symbol be in a fixed location relative to the edge of a thin substrate. Compare Slot Scanner.

slot scanner

Description applied to a specific type of omnidirectional scanner used for electronic point of sale applications, in which the scanning beams are directed through a window resembling a slot or pattern of slots.

space

An area of relatively high reflectance between the bars in a bar code symbol.

speck

See Spot.

spectral response

The sensitivity of a scanner or other device to light of different wavelengths.

specular reflection

Reflection from a surface in which the angle of reflection to normal equals the angle of incidence to normal. Compare Diffuse Reflection.

spot

An ink or dirt mark or other area of low reflectance in an area of a symbol which is intended to be of high reflectance. Compare Void.

stacked symbology

See Multi-row Symbology.

start character/pattern

An auxiliary character which indicates the beginning (left hand side) of a bar code symbol.

stop character/pattern

An auxiliary character that indicates the end (right-hand side) of a bar code symbol.

structured append

The linking together in a predetermined sequence of the data contained in two or more symbols, enabling the data to be handled as a single message. See Concatenation, Message Append.

substitution error

A character that is wrongly decoded when a bar code symbol is read. Compare Misread, Non-read.

substrate

The material or medium upon which printed matter (such as a bar code symbol or OCR characters) or a coating is imposed.

symbol

See Bar Code Symbol.

symbol architecture

The structure of a bar code symbol. See Symbology.

symbol aspect ratio

The ratio of the symbol height to the symbol width.

symbol character

The physical representation of the codeword as a pattern of dark and light elements. There may be no direct one-to-one mapping between symbol character and data character or auxiliary character. Decoding through the compaction rules is necessary to identify the data.

symbol check character

A symbol character calculated from the other symbol characters in a bar code symbol in accordance with an algorithm defined in the symbology specification and used to check that the bar code has been correctly composed and read. The symbol check character does not form part of the data encoded in the symbol.

symbol contrast

The difference between the maximum and minimum reflectance values in a scan reflectance profile.

symbol density

See Bar Code Density.

symbol width

The total width of a bar code symbol including the quiet zones. Also referred to as Symbol Length.

symbology

A standard means of representing data in bar code form. Each symbology specification sets out its particular rules of composition or symbol architecture.

symbology identifier

A sequence of characters, generated by the decoder and prefixed to the decoded data transmitted by the decoder, that identifies the symbology from which the data has been decoded.

tilt

Rotation of a bar code symbol about an axis perpendicular to the substrate. Compare Pitch, Skew.

tolerance

The largest permitted variation of a specified dimension or other value from its nominal value.

truncation

Providing a symbol with normal width but reduced height.

two-width symbology

A bar code symbology in which symbol characters consist only of narrow and wide elements the widths of which are in a constant ratio to each other. Compare Modular Symbology.

variable parity encodation

The process of encoding additional information in a series of symbol characters by using particular combinations of odd and even parity characters to implicitly encode digits or for checking purposes.

verification

The technical process by which a bar code symbol is measured to determine its conformance with the specification for that symbol.

verifier/verification instrument

A device used to measure and analyze quality attributes of a bar code symbol such as bar width and quiet zone dimensions, reflectances, and other aspects against a standard to which the bar code symbol should conform.

vertical redundancy

The property of a bar code symbol whereby there exist multiple possible scan paths as a result of the symbol being significantly higher than the height of a single scan line.

VLD (visible laser diode)

A laser diode operating in the visible light spectrum.

void

An area of high reflectance in an area of a bar code symbol which is intended to be of low reflectance. Compare Speck, Spot.

wand

Light pen.

wide:narrow ratio

The ratio of the widths of wider elements in a symbol to those of narrow elements.

X dimension

1. The specified width of the narrow elements in a bar code symbol. See Z Dimension. 2. The specified width of a single element in a matrix symbol.

Y dimension

The specified height of the elements in a linear bar code symbol or a row in a multi-row symbology. See also Bar Height.

Z dimension

The average achieved width of the narrow elements in a bar code symbol. It is equal to half the sum of the average narrow bar width and the average narrow space width, in two-width symbologies, or to the quotient of the average overall character width divided by the number of modules per character in modular symbologies.

zero-suppression

The process of removing zeroes from specified positions in a UCC-12 data string in order to encode it in UPC-E format.

Abbreviations:

EC:	Edge contrast
EC _{min} :	Minimum value of EC
ERN:	Element reflectance non-uniformity
ERN _{max} :	Maximum value of ERN
GT:	Global threshold
MOD:	Modulation
PCS:	Print contrast signal
SC:	Symbol contrast
SRD:	Static reflectance difference
V _{pp} :	Voltage peak to peak

Symbols:

A:	Average achieved width of element or element combinations of a particular type
e:	Width of widest narrow element
e_i : character	The edge to similar edge measurement, counting from leading edge of symbol character
K:	Smallest absolute difference between a measurement and a reference threshold
k:	number of element pairs in a symbol character in a (n, k) symbology
M:	Width of element showing greatest deviation from A
m:	Number of modules in a symbol character
N:	Average achieved wide to narrow ratio
n:	number of modules in a symbol character in a (n, k) symbology
R_b :	Bar reflectance
R_D :	Bar (dark) reflectance
R_L :	Background (light) reflectance
R_{max} :	Maximum reflectance
R_{min} :	Minimum reflectance
R_s :	Space reflectance
RT:	Reference threshold
RT_j :	Reference threshold between measurements j and (j+1) modules wide
S:	Total width of a character
V:	Decodability value
V_C :	Decodability value for a symbol character
Z:	Average achieved narrow element dimension

Annex A (informative)

Maintenance

In a technology that is still evolving, the terminology in use will likewise develop; new terms will come into use and the precise significance of existing terms may be modified. Pending the formal revision of this International Standard in accordance with the ISO/IEC rules, responsibility for maintaining the definitions of both new and modified terms has been assigned by ISO/IEC JTC 1/SC 31 to the SC 31 Vocabulary Rapporteur, from whom a regularly updated addendum to this International Standard may be obtained on request.

Vocabulary Rapporteur's address is:

SC 31 Rapporteur

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Web <http://www.qed.org/glossary/sc31orm.html>

Appendix C – LOCIS Concept of Operations (CONOPS) Version 12.0

The CONOPS is a living document that is periodically updated. Version 12.0, 21 December 1999, was analyzed during this project. The reader may contact the AFRL/HESR to obtain the most recent version.

Concept of Operations (CONOPS)

Version 12.0

For

Logistics Control and Information Support (LOCIS)

Insert New

LOCIS Logo

Prepared for:

U.S. Air Force Research Laboratory (AFRL),

Human Effectiveness Directorate

Deployment and Sustainment Division

Logistics Readiness Branch (AFRL/HESR)

Attn: Contracts Dept. AFRL/MLKH

Bldg. 7, 2530 C St. Buse Road,

WRIGHT-PATTERSON, AFB, OH 45433-7607

21 DECEMBER 1999

LOCIS Concept of Operations to Support LG/OG User Profiles

The objective of the CONOPS is to provide a realistic scenario of logistics processes that will support the demonstration of the LG/OG LOCIS functional capabilities. The CONOPS will be a living document that will be changed over time in order to enhance the CONOPS demonstration. The CONOPS has been broken down into time frames and describes the activities of LG/OG personnel during the day as they perform their tasks.

Background Information

The CONOPS is set in a timeline of activities involving a LG/CC (Col. Smith), the OG/CC (Col Jones), and additional LG and OG personnel who are vital to aircraft sortie production. Management effectiveness requires timely information distribution, thus, the LG and OG commanders generally hold meetings to review aircraft status, supply status, deviations from previous day's/week's activities, QDR, engine status, MICAPs, MC rates, scheduling effectiveness, flying windows, and a look ahead at the projected flying schedules.

CONOPS Functional Description to support LG/OG User Profiles

Although this scenario is written from the LG/OG's perspective, it is important to note that because of the LOCIS attributes described below, the LG/CC and OG/CC would not be finding new problems, but be made aware of potential problems that are already being worked by his personnel. This is just one high level case in point, several other scenarios could be written!

0700: OG going to Wing Operations Center/Maintenance Operations Center (WOC/MOC) and then to his office

1. The OG, Col. Jones, heads for the WOC/MOC first thing every morning. As he arrives outside the WOC, his pager goes off and indicates aircraft 0849 has just declared an air abort from his early morning mission and returning to base. As he walks into the WOC he notes the mission and aircraft status information which is displayed on wall panels from the LOCIS network. He sits at the senior controller's station and says "status 0849". Using voice recognition technology, the system displays this information on the screen before him and says, "0849 air aborted mission 03 for engine surges, will land at 0715 and be parked on L-3." Col. Jones notes the status of all the other aircraft in his fleet as they are reflected in the wall displays from LOCIS. As the FM radio net discusses aircraft status changes, the LOCIS voice recognition capability captures them and reflects them on the status wall. Content with the condition of the rest of his fleet, Col. Jones returns to his office.
2. At his personal computer in his office, Col. Jones logs in and sees problems from threshold limits he has previously set in LOCIS. Aircraft 0378 just returned from a cross-country flight with a repeat write-up. As he walks into his office, Col. Jones speaks his name to his computer, which is connected to the LOCIS network. Using voice recognition technology, the computer screen shows Col. Jones aircraft 0378 had a repeat malfunction in the Radar, Homing, and Warning (RHAW) system.
3. Since repeat and recur discrepancies have been a problem in the past (especially with the RHAW system), and the threshold of three repeat/recur problems on an aircraft has been exceeded, LOCIS automatically provides additional information. This information was

remembered by LOCIS from previous instances when Col. Jones was concerned about repeat discrepancies. The information automatically came up on the screen because Col. Jones had just been notified of the problem by LOCIS through his pager. Col. Jones sends an e-mail to the LG, Col Smith, asking him to have his Component Repair Squadron (CRS) commander look into the repeat problem. Also on the repeat screen is a pull down window in the corner with the five most common screens he asks for at this time in the flying day. At the same time the OG is reviewing his screens, the avionics superintendent receives a pager notification that a repeat/recur discrepancy has occurred on one of the avionics work unit codes (WUC) thresholds he has established. The superintendent's presentation displays all the past personnel who performed the corrective action and all of their detail qualifications. He then forwards all the detail data to the avionics supervisor, knowing that he will have to brief the LG.

4. Instead of receiving a very static and untimely status report from the MOC, the OG can simply access his normal morning review screen, the Daily Recap Page that he personalized on LOCIS. LOCIS accesses the most up-to-date information from CAMS, SBSS, etc. and displays it in the format that Col. Jones has specified. LOCIS displays the standard morning package information that every OG might want to view such as, A/C status, Code 3 breaks, and aborts. Col. Jones has customized his status package so that he can quickly look at the screen and get all the pertinent information he requires without being deluged with unnecessary data. LOCIS will also inform the OG of all personnel that were notified of the problem and what corrective actions they have taken to correct the problem.

5. Since Col. Jones knows that the RHAW system has been a huge problem for the wing, he accesses his e-mail to send a quick note to the LG and the Deputy Operations Group for Maintenance (DOG/MA) saying that they need to discuss this problem.

6. Col. Jones then enters a bookmark on the Daily Recap Page to indicate a note to inquire about the 8-hour fix rate icon, which is yellow, during the morning Operations meeting.

7. In the mean time the LG, Col. Smith, is also reviewing his morning screens. He notes an icon indicating a threshold condition for MICAPS. He then clicks on the MICAP icon and LOCIS highlights that as of yesterday, the wing had a total of two F-16 transparencies MICAP with due in dates of 4 Jul and 24 Aug. The 2nd Fighter Squadron ordered a third transparency this morning, bringing the total to three. In addition to the pertinent part and mark-for information, LOCIS displays information pertaining to base supply, part history and the depot point of contact information (item manager, supply liaison). LOCIS also displays the actions taken by supply to resolve the two previous MICAPs and Col. Smith notes that the depot has one of the wing requisitions earmarked for the first transparency off the depot repair line tomorrow.

8. Col. Smith knows that F-16 transparencies are of a particular concern to the OG/CC, so he sends a quick e-mail to the supply commander asking him to keep him notified of any problems in this area. The MICAP section chief has established his threshold to be notified of all critical assets not resolved within 2 days. He knows that LOCIS will continually update the status to all key personnel on a daily basis, and that with LOCIS data fusion capability, it will present detailed information pertaining to each part to include serial number, nomenclature, priority, stock number, suitable substitutes, estimated delivery date, etc. Col. Smith finishes looking at his Daily Recap Page and concludes that all in all yesterday was not a bad day for the Wing. A few minor glitches, but nothing out of the ordinary.

0730: OG's Office

9. After looking at yesterday's flying schedule, Col. Jones moves on to look at what today has in store for the wing. LOCIS displays the main status screen with icons for all of the squadrons that support sortie generation including 1st, 2nd, and 3rd Fighter Squadrons, Equipment Maintenance Squadron (EMS), and Component Repair Squadron (CRS) showing how many aircraft are scheduled to fly that day. Drilling into each fighter squadron icon, the OG can quickly see the number of aircraft at home station, their status, location, in-progress maintenance ETIC, and programmed activity for today (scheduled maintenance, flyer, spare, etc). The 1st Fighter Squadron production superintendent is having a meeting with his expeditors when his pager goes off. He reads the text telling him that the AGE required to support the first few flying lines might be short, based on his pre-established threshold level. He sends a message to the 1st Squadron Combat AGE driver to give him a heads-up to the potential problem.

10. Col. Jones notices that the AGE icon is yellow, and that the LG, AGE flight chief and EMS superintendent have been working the problem since earlier because their out-of-threshold warnings were set at levels lower than his.

11. Getting back to the main flying schedule screen, Col. Jones also notices that the SORTS icon (for mission essential equipment) is yellow indicating an out-of-threshold number of aircraft in PMC status. The threshold level is six, and eight aircraft are PMC.

0800: OG's Office

12. Since the wing is tasked with the CORONET LIGHTNING (C/L) deployment, Col. Jones has created a LOCIS screen to show how well the wing is prepared to deploy if the horn went off. This screen would show the anticipated results of the LOCIS decision support simulation evaluating the wing's logistics resources against its CORONET LIGHTNING mission requirements.

13. Clicking on the yellow equipment status icon, Col. Jones is shown that two of the items on the C/L UTC are also listed on the SORTS report this morning: the RHAW pulse box and the memory load verifier (MLVT). LOCIS also shows him that the LG and CRS maintenance superintendent are already aware of the situation.

0830: LG's Office

14. The wing's budget status is a very important aspect of resource management. Over the past few months, the wing has been looking very closely at the depot level reparable (DLR) float. With over \$2M in the float, the wing commander has been concerned that they are becoming somewhat complacent. Using the same principles and data as the Intermediate Repair Enhancement Program (IREP), Col. Smith has established a report within LOCIS that highlights LRUs that have been sitting in one place too long or have been in the float for over 40 days. In addition to the normal information, LOCIS also identifies prime drivers for the float, including any LRUs that are high cost or high failure items.

15. Col. Smith notices that the icon for the DLR Float is red. He e-mails the material control OIC asking for an update on the DLR Float. The NCOIC of material control has already been sent the notification prior to the alert notification being sent to his supervisor. He was alerted based on his established thresholds such as: the number of NMC aircraft that are being affect by not having the part available, or the cost of the high value items. He has designed his customizable screen to automatically display all pertinent data and to present options on the availability of parts at different locations within the command.

16. Getting back to the main financial management area, LOCIS has also colored the prime driver icon yellow. Drilling down on the icon, Col. Smith is informed that the wing currently has two advanced programmable signal processors (APSP) in the DLR float while the wing is also currently MICAP for another APSP. The LOCIS screen has provided all of the associated part information (NSN, nomenclature, cost, base supply history, repair cycle averages, NRTS rate, MICAP data, and MICAP history). Looking at the data, Col. Smith sees that the wing only NRTS about 65% of the APSPs turned in from the flight line and that both LRUs in the float are currently in the repair cycle in the avionics backshop. Col. Smith decides to ask the CRS/CC about this issue.

0900: The Flightline

17. While driving on the flight line, the EMS/CC receives a page on his pager/cell phone system. The pager function alerts the EMS/CC that the AGE support for the flying schedule has fallen below the critical threshold and is now in danger of impacting the operational mission. LOCIS has included the specific data showing five Dash 60s FMC, with a total of six NMC. Concerned about the potential impact, EMS/CC sends an e-mail to EMS superintendent's pager and asks him to look into the problem. He finds out the AGE flight chief had already been notified via LOCIS and has addressed the problem.

18. Driving on the flight line, the OG/CC decides to look at the latest weather report via his palm pilot since snow was expected sometime this week. He sees that a possible snowstorm may pass through the area at 1800 hrs. He decides to give the SQ/CCs and SMOs the same heads-up since they may want to prepare to place aircraft in hangars on night shift. He sends a message to their pagers from his palm pilot.

0930: LG/OG Stand-Up Meeting

19. Using LOCIS to project current AGE status and information, Col. Smith walks through each area addressing his concerns to the pertinent parties. Under the SORTS equipment icon, he notices that one of the RHAW pulse boxes has been calibrated by PMEL and that the other is due out in the next hour. The supply supervisor also briefs him that the item manager for the MLV is no longer providing field support in anticipation of a new acquisition. The backorder dates for the MLVs are only estimates and could realistically go longer than anticipated. The supply representative recommends that an e-mail be sent to the depot under the LG/CC signature requesting priority assistance for field support. Col. Smith agrees and asks that the e-mail to be forwarded to his office by COB today.

20. Col. Jones quickly goes over the items of interest that LOCIS highlighted during his daily recap. Col. Jones goes to the 8-hour fix rate and asks about the trend toward longer fix times. The 3rd Fighter Squadron responds that personnel availability was an issue and that the problem has been corrected. Drilling down in the repeat/recur icon, Col. Jones discusses his concerns about the RHAW system. With several aircraft having five malfunctions in the RHAW system over the past month and three of the corrective actions to be CND, Col. Jones is concerned that there is still an underlying problem that has not yet been fixed. The 1st Fighter Squadron SMO agrees and says the latest aircraft, 0378, is not a flyer today and is slated for unscheduled maintenance (USM). He will have an avionics specialist perform a detailed system operational checkout to see if they can pinpoint the problem and fix it this time around.

21. The 2nd Fighter Squadron SMO briefed Col. Jones, Col Smith, and the Supply/CC that they are very quickly going to run into problems due to a lack of F-16 canopy transparencies. Last

night, the 2nd Fighter Squadron went MICAP for another canopy, bringing the wing total to three. The supply supervisor informs Col. Smith that the F-16 transparencies have been a problem over the past few months and using his palm-pilot and LOCIS capabilities, he instantaneously downloads its real-time backorder history. Looking at the backorder history, Col. Smith sees that the wing has ordered eight transparencies in the last 6 months. The supply representative said they would contact the item manager to try and expedite the MICAPS. Looking at the depot stock level, Col. Smith sees there are currently four other depot requisitions for transparencies, and that two transparencies were shipped out yesterday to USAFE. Col. Smith advises the supply superintendent to call the item manager.

22. Col. Jones and Col. Smith quickly go through the rest of the fields on the Daily Recap and Today's Flying Schedule screens discussing all of the areas that LOCIS highlights as potential problems. EMS/CC stated that they are working the Dash 60 problem and expect to have a fix in the next few hours. CRS/CC also briefed that the fighter squadrons did not turn the RHAW pulse boxes in on time, resulting in two pulse boxes being NMC for overdue calibration. PMEL now has the pulse boxes and have pushed one box out already and expect to push the other out in the next hour or so.

23. OG/CC emphasizes the need for everyone to work together to ensure problems like this do not happen again. He then brings up the information for the C/L readiness. Looking at the screen he reviews the 3rd Fighter Squadron status. He notices the 2nd and 3rd FSs have worked together to swap out NMC aircraft to make the flying schedule front lines. Before he could get any further, Col. Jones and Col. Smith receive notification on their pagers from the command post advising them that an Air Tasking Order (ATO) was just received, and to report to the command post ASAP.

1000: OG and LG go to the Command Post

24. After reporting to the command post, the group commanders are briefed that ACC has issued a CORONET LIGHTENING deployment ATO for 18 aircraft and support equipment, deploying to a bare base location. Col. Smith uses the command post computer; he sends an e-mail to his Log Plans office to have them check LOGCAT for conditions at the site. Looking at the ATO, the group commanders see the mission calls for suppression of enemy air defenses and requires the aircraft to be in-theater within the next 36 hours. The command post has started the standard notification procedures, ensuring that all applicable personnel have been notified. RST is set at 1000 hours. The senior MOC controller display has a flashing icon, displaying "CORONET LIGHTENING TASKING has been received" (his established threshold). Using voice recognition he states "Coronet Lighting" to his desktop computer. The LOCIS information fusion capability has already reviewed the MESL requirements and aircraft status of the wing's assigned aircraft. Next, LOCIS presents a listing of all the aircraft that are configured to meet the 8-hour generation period. This information is immediately sent to the command post for dissemination.

25. Because LOCIS has previously evaluated this scenario, Col Jones and Col. Smith can access a list of potential problems and shortfalls for this deployment and provide it to the command post electronically.

1030: LG in the Command Post

26. During contingencies some MOC personnel are assigned to the WOC to handle the generation. Normally, MOC becomes the secondary WOC. LOCIS will have to prioritize who at the same level will be able to change thresholds and how the hand-off of authority might be handled.

27. While in the command post, the OG/CC wants to review how prepared the aircraft are for the C/L deployment. Entering his login information into an available LOCIS computer, Col. Jones accesses the CORONET LIGHTNING deployment status display and sees the 3rd Fighter Squadron and the MOC have already broken the 24 aircraft into 4 different cells of 6 aircraft each. The spread of the FMC and NMC aircraft appears to be good, with 16 aircraft being FMC (green), 7 aircraft being NMC with ETICs in the next 4 hours (yellow), and 5 aircraft being NMC with ETICs over 4 hours (red) to bring the number of spares to 4.

28. Col. Jones notes the slowly changing locations of the aircraft in each cell, reflecting that the aircraft are being towed to the proper spots. Drilling down into the C/L timeline, Col. Jones sees the MOC has established the sortie generation timeline for the deployment, breaking the activities into six main categories and assigning aircraft to each takeoff block. Col. Jones then logs out of LOCIS and leaves the command post for the flight line.

1100: 1st FS/Production Superintendent

29. As the 1st FS production superintendent is walking around the flight line, he receives another threshold notification on his pager/cell phone. Reading the message, he discovers EMS brought one of the Dash 60 carts back up to FMC, changing the AGE support icon from red to yellow. LOCIS accesses information on all assigned Dash 60 carts and relays it to the 1st FS SMO via his personnel communicator. There are now six Dash 60s FMC (enough to support the deployment) and five NMC. One of the NMC Dash 60s has an ETIC within the next 3 hours, providing even more relief.

1115: LG/CC Goes to CRS

30. Walking around CRS, Col. Smith sees that each flight's mobility pallets are progressing very quickly and decides to head over to the CRS commander's office. While discussing the deployment with the CRS commander, Col. Smith notices she has set up her LOCIS screen to specifically highlight problems within her squadron. Looking at the screen, Col. Smith sees the avionics flight icon is yellow. He watches while she drills down for more information. They see the electronic countermeasure (ECM) shop icon is red. Drilling for more information, they learn that the shop has more than six pods AWM.

31. Wondering how this would impact the deployment, Col. Smith has the CRS commander log out and he logs back in the CRS/CC computer. Seeing the CRS icon was green, Col. Smith drills down to the ECM shop and sees his LOCIS screen has accessed the same information. Clicking on the "New Threshold" area, Col. Smith quickly creates a new threshold to have LOCIS alert him if more than six pods go AWM. LOCIS automatically updates the CRS commander threshold to five.

32. The ECM shop chief has already custom-designed his screen displays to support tracking of all critical assets to include LANTIRN and targeting pods assigned to the shop. Also, he has established a lower threshold to ensure that he is informed way in advance of any problems in order to take the appropriate corrective action.

1130: LG goes to the Mobility Processing Center (MPC)

33. Going into the MPC, Col. Smith sees the transportation commander has set up LOCIS to track the progress of mobility processing. Looking at the screen, Col. Smith sees the spread of when each UTC's pallets are due in to the MPC and when the respective airlift should be arriving. Col. Smith also sees the first three UTCs have already been brought to the MPC and have cleared

pre-check. LOCIS highlights to the commander that the first UTC is on time, and the second two are ahead of schedule. Col. Smith asks the MPC supervisor to drill down on the first UTC to see what unit it is assigned to and what equipment is packed in the pallets.

34. LOCIS also identified that several of the contents of the first UTC contained hazardous material. From its database, LOCIS has identified that this particular UTC caused a frustrated cargo situation during the last deployment.

1200: DOG/MA in his office

35. In his office, the DOG/MA's personal communicator alerts him to a potential problem. Reading the message, he realizes an aircraft part (one of the prime drivers for ground aborts) just went to a zero stock level on base.

36. He contacts the Aircraft Parts Store superintendent and asks about the red supply icon. Drilling into the information, LOCIS displays all of the pertinent information on the digital flight control computer (DFLCC) including NSN, cost, order history, base stock level (showing zero in normal stock and four in the WRSK kits,) depot stock level, and ground abort history.

37. Looking at the information, LOCIS identifies that the wing has experienced 23 red balls or ground aborts over the past 6 months, resulting in the DFLCC being replaced. Looking at the base supply history, apparently one was just taken from stock control to be included in the WRSK kits for the impending deployment. LOCIS also provided a list of options to ensure that a DFLCC is on-hand for the generation.

1215: OG driving back to the Command Post

38. Driving back to the command post, Col. Jones reviews the C/L sortie generation status screen on his palm pilot. Col. Jones sees the generation is progressing fairly well. Looking at the launch times, Col. Jones feels pretty confident that the wing will be able to fully meet the deployment.

1230: OG and LG in Command Post

39. While in the Command Post, Col. Jones was approached by the wing commander and asked how well the wing sortie generation and deployment was going. Going to the command post computer, he activates the screen by voice command. Col. Jones shows the Wing/CC the C/L generation screen. He also shows the previous LOCIS simulation evaluation of the wing's ability to support this requirement. Seeing the line-up, the wing commander asked why the aircraft in D cell were not all FMC. Drilling down on one of the NMC aircraft's status screen, he sees all open discrepancies, in-progress maintenance ETICs, work history, sortie history, and parts ordered.

40. Looking at the screen, the wing commander can quickly see that aircraft 1396 is hard broke for an "Auto Transfer to Sec" failure, which resulted in an in-flight emergency on its last flight. Looking at the flight history, the wing commander sees that LOCIS has positively identified a trend over the past 3 months for engines. Col. Jones reminded the wing commander that since the first three cells have all FMC aircraft, D cell will usually only have to generate one or two aircraft to fulfill the deployment in addition to possible extra spares from the first cells.

41. Switching to the MPC status screen in LOCIS, Col. Smith shows the Wing/CC that all of the UTCs are progressing as advertised. Looking at the screen the wing commander sees the first UTC is already loaded on the first airlift. Looking at the screen, the Wing/CC asks if five

different UTCs will all fit in the KC-10 that just landed for Chalk 2. Drilling down on the aircraft icon for Chalk 2, LOCIS displays to the wing commander that the proposed load is much lower than the maximum for the KC-10 based on LOCIS' data fusion from different databases (Logistics Planning Software).

42. After the wing commander walked away, Col. Smith went back to the main MPC status page and saw that LOCIS had already updated the screen to reflect the inbound aircraft information that was just received from the Air Mobility Command (AMC) Support Aircraft Section.

1400: LG goes to the Mobility Processing Center

43. As Col. Smith walked into the control center of the MPC, he notices that Chalk 7 had a red flashing icon on the pre-check time block. Asking the controller what was going on, Col. Smith discovered that Chalk 7 was due in to pre-check at 1330, and has not been called in yet.

44. Wondering why LOCIS did not alert him to the situation, Col. Smith asks that the MPC status screen be pulled up and sees that LOCIS indeed had identified that Chalk 7 was due in at 1330, but had not changed the icon color threshold yet. Since Chalks 1-13 were critical for the re-generation effort at the deployed site, Col. Smith adjusted his LOCIS threshold to alert him at the 30 minute point, instead of at the hour.

45. After adjusting the threshold, LOCIS immediately changed the icon to yellow. If the situation was not corrected soon, Col. Smith knew that the icon would go to red, meaning that Chalk 7 would most likely be frustrated equipment, causing a delay in the deployment airlift.

46. While Col. Smith was looking at LOCIS, the Cargo Deployment Function (CDF) NCOIC walked back up and informed him that EMS supervision reported that they dropped off Chalk 7 at pre-check over an hour ago. When Col. Smith asked why the pre-check personnel had not called it in yet, the controller informed him that pre-check personnel were getting swamped with pallets being dropped off too early. Looking back at LOCIS pre-check display, he could see that almost half of the first 13 chalks had already been dropped off at pre-check, causing a back up.

47. The CDF NCOIC told Col. Smith he informed all squadron mobility NCOICs that they should not bring their pallets to pre-check until their designated time period for their chalk number.

48. Just out of curiosity, Col. Smith uses LOCIS to pull up the UTC information for Chalk 7. He sees that Chalk 7 is primarily munitions equipment essential to building up Mk-82 and Mk-84 bombs for the regeneration. This is a critical UTC, since the deploying aircraft are required to fly enemy suppression missions immediately after re-generation.

1430: LG goes back to the Command Post

49. Prior to the LIMFAC e-mails being sent to ACC for the RST+5:00 deadline, Col. Smith reviews the various e-mails to see for which items the wing is asking for command assistance. While he was looking at the e-mails, Col. Smith reviews the equipment readiness screen to see that LOCIS has already compared the items listed on the SORTS and MICAP report and those required to support various UTCs into detail options that he can choose from.

50. Looking at the summary of e-mails, Col. Smith sees that supply had submitted a LIMFAC for the DFLCCs and the F-16 transparencies for the WRSK kits. Upon finishing the LIMFAC e-

mail, Col. Smith realizes LOCIS has also identified the MLV as a potential problem, but no LIMFAC e-mail was submitted for it. Col. Smith calls up the DOG/MA and asks him about the MLV. He said that he would look into it and e-mail a LIMFAC, if required. If needed, one of the MLVs used for the generation could be put on one of the later chalks.

1500: 1st FS/ Production Superintendent on Flightline

51. Wondering how the generation was progressing, 1st FS pro-super pulled up the C/L generation screen within LOCIS. Looking at the screen, LOCIS has flagged that A cell is 5 hours ahead of schedule, with the next activity to be the leak and transfer check at 2000 hrs.

52. Looking at the status screen, the icon for aircraft 3366 in D cell turned yellow. 1st FS pro-super contacts the sortie generation D cell supervisor and inquires about aircraft 3366.

1600: LG Office

53. Col. Smith sees the C/L generation is progressing satisfactorily and he needs to spend time on a proposal that is to be presented to the Wing/CC and staff next week. The LOCIS data will support the proposal to begin a project to refurbish the F-16 fuel tanks. He was reminded of the need to review this work by the CRS completion of the fuel problem on aircraft 3366. Fuel system discrepancies were becoming a problem; this trend had been verified by LOCIS during a review of trends for all the various WUCs pertaining to the fuel system. Periodically, Col. Smith would use a special set of thresholds and simulations to check for areas that could become problems in 6 months. The fuel system popped up as the most serious and he had tasked the CRS commander to propose a fix. He has their data and recommendations via an e-mail.

54. A LOCIS simulation showed that with the projected rotation of several key personnel, two planned long range deployments and the increasing shortage of fuel systems parts would cause an increased number of aborts and NMCS aircraft. The simulation also took seasonal changes into the equation and how they compounded the problem.

55. Col. Smith reviewed the proposal from CRS commander, which stated their solution to the problem and their plan to have it resolved prior to the commencement of winter flying operations. The plan looked very good and would take an entire wing effort to implement as LG, OG, and other wing resources were to be tasked.

56. While his thoughts were on wing staff matters, he remembered he had been asked by the Wing/CC on several occasions about emergency requisitions. He made a bookmark to tailor his daily status screen and have this information provided for presentation to the staff.

57. Clicking back on the deployment status screen, he saw everything was under control. The first cell was ready to depart on schedule and the remainders were progressing according to plan.

58. As the OG heads towards his car at 1830 hours his pager alerts him to another potential problem via text display. It read "aircraft 4517 In-Flight Emergency--Engine Vibration." He goes back into his office and the screen on his desktop computer is flashing a red alert icon. Based on his voice response, his screen displays all the emergency equipment and personnel that are available on shift that are responding to the situation. (LOCIS had accessed several different databases to retrieve detail information pertaining to the availability of equipment status, personnel, and other resources.) Simultaneously, the senior MOC controller's pager goes off, indicating an in-flight emergency has been declared (his established threshold). Using voice recognition, he states "In-Flight Emergency" to his desktop computer. LOCIS has already

notified the appropriate crash recovery duty section, hospital, and civil engineer control centers of a potential problem. Before the MOC senior controller could contact additional personnel, LOCIS had already been updated with the cancellation of the in-flight emergency and automatically cancelled the request for personnel and equipment.

59. Col. Jones finally departs his office, and driving home he reflects on his day and how technology has finally started to live up to some of its promises to improve logistics. The end result of the LOCIS technology is just what the logisticians wanted—Right Information -- To the Right People -- In the Right Format -- At the Right Time.

List of Abbreviations/Acronyms

The following list represents the abbreviations and acronyms used in this document.

ACC	Air Combat Command
AFK	Air Force Munitions Designation
AFRL	Air Force Research Laboratory
AFB	Air Force Base
AGE	Aircraft Ground Equipment
AMC	Air Mobility Command
APSP	Advanced Programmable Signal Processor
ATO	Air Task Order
AWM	Awaiting Maintenance
CAMS	Core Automated Maintenance System
CBOP	Combat Operations
CMSGT	Chief Master Sergeant
CND	Could Not Duplicate
CONOPS	Concept of Operations
CRS	Component Repair Squadron
DID	Data Item Description
DLR	Depot Level Repairable
DOGMA	Deputy Operations for Maintenance
ECM	Electronic Countermeasures
EMS	Equipment Maintenance Squadron
ETIC	Estimated Time In Commission
EWS	Electronic Warfare System
FMC	Fully Mission Capable
FW	Fighter Wing
HESR	Human Effectiveness Directorate, Deployment and Sustainment Division, Logistics Readiness Branch
LANTIRN POD	Low Altitude Navigation and Targeting Infrared System for Night
LG	Logistics Group
LGCC	Logistics Group Commander

LGCD	Logistics Group Deputy
LIMFAC	Limiting Factors
LOCIS	Logistics Control and Information Support
LOGCAT	Logistics Contingency Assessment Tool
LOX	Liquid Oxygen
LRU	Line Replaceable Unit
MDS	Mission, Design, Series
MESL	Mission Essential Subsystem List
MICAP	Mission Capability
MLV	Memory Load Verifier
MNA	Marconi North America
MOC	Maintenance Operations Center
MPC	Mobility Processing Center
MSGT	Master Sergeant
NCO	Non-Commission Officer
NCOIC	Non-Commissioned Officer in Charge
NMC	Not Mission Capable
NMCS	Not Mission Capable Supply
NRTS	Not Repairable This Station
NSN	National Stock Number
OG	Operations Group
OGCC	Operations Group Commander
OIC	Officer in Charge
PMC	Partially Mission Capable
PMEL	Precision Measurement Equipment Laboratory
QA	Quality Assurance
QDR	Quality Deficiency Report
R&D	Research and Development
RHAW	Radar, Homing, and Warning
SBSS	Standard Base Supply System
SI&T	Systems Integration and Test
SMO	Squadron Maintenance Officer
SMS	Senior Master Sergeant
SMSGT	Senior Master Sergeant
SQ	Squadron
USAFE	United States Air Force Europe
USM	Unscheduled Maintenance
UTC	Unit Type Code
WG/CC	Wing Commander
WOC	Wing Operations Center
WRSK	War Readiness Spare Kit
WUC	Work Unit Code