IDA

INSTITUTE FOR DEFENSE ANALYSES

Selected Issues in DoD's Radio Frequency Identification (RFID) Implementation

Christine Youngblut
Sarah H. Nash

Michael S. Nash, Task Leader

April 2006
Approved for public release;
unlimited distribution.
IDA Paper P-4094
Log: H 06-000161

This work was conducted under contracts DASW01 04 C 0003 and W74V8H 05 C 0042, Task DE-5-2452, for the Defense Logistics Agency (DLA). The publication of this IDA document does not indicate endorsement by the Department of Defense, nor should the contents be construed as reflecting the official position of that Agency.

INSTITUTE FOR DEFENSE ANALYSES

IDA Paper P-4094

Selected Issues in DoD's Radio Frequency Identification (RFID) Implementation

Christine Youngblut
Sarah H. Nash

Michael S. Nash, Task Leader

Preface

This document was prepared by the Institute for Defense Analyses under the task order Defense Logistics Agency (DLA) IT-Based Supply Chain R&D. It partially fulfills the objectives of the task, being a necessary preparatory step to identifying and addressing DLA-specific issues.

Many people contributed to this work by providing the information documented here. We are grateful for all such contributions. This document was reviewed by IDA research staff members, Dr William E. Cralley, LTG Peter A. Kind (Ret)., Dr. L. Roger Mason, Jr., and Dr. Richard P. Morton.

Contents

List of Figures

List of Tables

Executive Summary

The DoD Radio Frequency Identification (RFID) Policy ("Policy"), issued 30 July 2004, requires DoD components to immediately implement the use of active RFID for all Outside Contiguous United States (OCONUS) shipments and states that the Defense Logistics Agency (DLA) is the procurement activity and single manager for active RFID tags. The Policy also specifies the business rules for a phased introduction of the use of passive RFID on shipments in the DoD supply chain.

Several recent activities have moved DoD closer to full Policy compliance. A new Defense Federal Acquisition Regulation Supplement (DFARS) rule was published on 13 September 2005, all affected DoD components had delivered RFID implementation plans to ADUSD (SCI) by December 2005, and five Blanket Purchase Agreements have now been awarded to facilitate implementation of the necessary RFID infrastructure. Steps taken by industry will also benefit DoD, for example, EPCglobal has revised its EPC tag data standard to incorporate DoD's Commercial and Government Entity code and the DoD Activity Address Code. Nevertheless, there are some outstanding issues, particularly with regard to Service funding and spectrum management for RFID equipment.

DoD has been using active RFID technology for sustainment cargo for over a decade, primarily to provide Combatant Commanders with in-transit visibility of shipments in the supply chain. Over the last few years, DoD has been involved in several efforts that are looking at how best to exploit technology advances. The Air Force has led an effort investigating how augmenting active RFID tags with environmental monitoring can best support the DoD supply chain. Part of this work included in an Advanced Concept Technology Demonstration ended with a positive Military Utility Assessment. The Army is collaborating with the Air Force in looking at new application areas for this technology. There are plans to investigate the potential of new types of active tags that enable monitoring shipping container security. Other work is determining the best mix of communications technologies for providing on-demand location of shipments where there is no preexisting RFID infrastructure. DoD components are also looking at new ways of using the existing technology, with applications ranging from container management to tracking parts through lengthy overhaul and repair processes.

DoD has less experience with the use of passive RFID technology and most current efforts are identified as pilots or proof-of-concept studies. The majority of these efforts have had successful outcomes. This is particularly notable for the two that were conducted as field trials where passive RFID tags were used in operational processes. It is also encouraging to note that, between them, these two efforts have examined most ways in which the technology can be used in the supply chain. The outstanding gap is exploiting the information provided by the technology for logistics decision-making, such as automated reordering of stock once available supplies reach a threshold value.

As yet, there is no evidence of integrated use of active and passive tagging of data. Some efforts have captured manifests on active tags attached to shipping containers, but this data does not seem to have been used at other nodes in the supply chain. However, one demonstration that used passive and semi-passive tags in a simulated supply chain has validated the concept. Currently in development, the Alaska RAPID project will be the first major demonstration of this capability in an operational environment.

Standards are important for the device and data interoperability required for seamless use of RFID across the supply chain. Since DoD's operations span many continents, the pending ISO ratification of EPCgobal's Class 1 Generation 2 (Gen 2) specification is important because World Trade Organization treaties require that ISO be employed by signatory nations.

There is little evidence of DoD component planning for RFID education and training. The Air Force, Army, and Navy are waiting for guidance from DoD LOG-AIT, although the Army has some experience in training personnel using active RFID equipment. Education and training is especially important for passive RFID where some problems that have been encountered, for example, poor tag read rates, are affected by personnel actions.

DLA has identified several issues that need to be addressed. Most are process-oriented. These include:

- Loss of in-transit visibility due to the loss of active tag capability after shipments have left DDCs,
- Potential contamination of packing materials caused by passive tags; and
- The need to tag objects, such as sheets of maps, where the close proximity of tags introduces new technology-related problems.

IDA has identified several additional issues that relate either to overall implementation concerns or to innovative uses of RFID technology that have the potential to impact war operations success and mission accomplishment. These are:

- The lack of a common architecture for RFID implementation,
- The lack of an operational viewpoint in identifying DoD's RFID requirements,
- The need to look beyond the commercial market to identify DoD-specific technology needs,
- Uncertain maturity of readers and tags that operate across the 860 to 960 MHz frequency range,
- A lack of understanding of tag performance in operational environments, including those environments with reduced power requirements,
- Evaluating the potential of read-write passive tags whose data can be changed after initial printing; and
- Evaluating the potential of packaging cases and pallets with embedded passive tags.

All these issues require further investigation, either to determine cost-effective resolutions or to maximize the benefits of DLA's use of RFID technology for the warfighter.

1. Introduction

Purpose

This report articulates the big picture of Department of Defense (DoD) Radio Frequency Identification (RFID) activities with the purpose of identifying RFID-related issues specific to the Defense Logistics Agency (DLA).

There is already a large body of literature, from formal reports to short articles, on DoD's use of RFID technology. From these sources, interviews conducted with relevant groups, and discussions with representatives of the RFID efforts discussed here, we have collected the essential elements to provide a synopsis of DoD past experience, current activities, and plans for the future with RFID. The result is a baseline against which an initial assessment of the scope and criticality of DLA concerns can be made.

It is important to stress that the path to such major changes as DoD envisions with the introduction of RFID technology is a difficult one. Despite delays in completing certain mandated actions, DoD components are making significant progress in meeting policy requirements. In preparing a report such as this, it is easy to note problems and deficiencies. All too often, issues that have been successfully resolved become 'invisible' and do not achieve the notice they should.

Scope

The scope of this work is the use of RFID technology for supply chain operations, including asset management. (We have not addressed use of the technology for other types of applications, such as border security.) We address uses of active, passive, and semi-passive RFID technology with a primary focus on passive RFID. The discussion on active RFID is largely limited to those areas where technology developments are opening up new uses and uses that move beyond in-transit visibility (ITV). Our view of passive RFID technology includes semi-passive RFID technology, where a passive tag is augmented with limited battery power and sensors to monitor environmental conditions. We also cover the integration of active and passive tagging, although work in this area is in its earliest days.

Our development of the baseline picture of DoD's RFID activities, and the factors that influence them, addresses the following topics:

- The status of policy implementation documents being developed by various DoD components,
- The scope of DoD RFID projects, with respect to both the coverage of DoD supply chain nodes and the business processes applicable at each node,
- The current status of relevant standards and regulations; and
- The current status of RFID-related training.

This report does not cover some relevant topics. In particular, it does not provide an overall view of architecture issues with regard to the integration of RFID data into logistics automated information systems (AISs), nor does it provide a thorough discussion of plans to deal with RFID-related security issues.

This report does not discuss the basics of RFID technology. A description of technology fundamentals can be found at http://www.rfida.com/index.htm. A glossary of RFID terms is included in Appendix A.

Document Structure

The structure of the following sections follows the topics listed above. Section 2 reviews the current status of the Concept of Operations (CONOPS) and other implementation documents being prepared by DoD components. This Section pays particular attention to how problems identified in the recent Government Accountability Office (GAO) reports, *Better Strategic Planning Can Help Ensure DoD's Successful Implementation of Passive Radio Frequency Identification* [GAO-05-345, September 12, 2005] and *Defense Logistics: More Efficient Use of Active RFID Tags Could Potentially Avoid Millions in Unnecessary Purchases* [GAO-06-366R], are being addressed. Section 2 also identifies outstanding issues identified by DoD components and GAO.

Section 3 covers current investigations into the use of active RFID technology. It does not repeat material presented elsewhere on DoD's extensive experiences in using active RFID for ITV. Here, the focus is on recent investigations into using the technology in non-traditional ways, and on technology advances. Section 4 covers DoD's use of passive RFID technology, reviewing the scope of the various passive RFID projects that have been conducted, or are in progress, by DLA, the Services, and the U.S. Transportation Command (USTRANSCOM). We have mapped these efforts against the supply chain nodes they cover and the business processes that have been examined. Section 5 discusses current plans for investigating the integrated use of active and passive technology. The efforts discussed in Sections 3, 4, and 5 do not provide an exhaustive identification of all DoD RFID-related work. Instead, they are intended to form a representative subset.

There are a growing number of standards that pertain to RFID. Section 6 reviews the current status of these standards, providing insight into issues, such as the degree of device and software interoperability that can be expected in the near-term. Training is covered in Section 7. Since most of the Services are waiting for DoD guidance on education and training, there has been little activity to date.

The final part of this report, Section 8, discusses DLA-related issues that have been identified, providing a brief statement of recommended actions for each.

2. Policy Implementation

The final version of the DoD RFID Policy (the "Policy") was issued 30 July 2004 [DoD 2004]. This Policy requires DoD components to use RFID technology, while a subsequent amendment to the Defense Federal Acquisition Regulation Supplement (DFARS) requires that contracts with DoD suppliers include a clause requiring them to take the necessary actions to support DoD's use of the technology. A September 2005 GAO report identified several concerns with DoD's approach to RFID adoption and there are additional issues pertaining to component funding and spectrum management. In addition to meeting the requirements of the Policy, DoD users of RFID technology have to conform with DoD instructions and directives pertaining to ordnance, fuel, and personnel safety.

Policy Requirements

DLA has played an active part in supporting the Policy. The Policy requires each DoD component with a role in the DoD supply chain to prepare a plan for its implementation of RFID and gives DLA additional responsibilities. The Policy specifies that DLA is the procurement activity and single manager for RFID active tags.

Component Planning

In September 2004, DoD issued a Concept of Operations (CONOPS) [CONOPS 2004] that outlined the transformational role of active and passive RFID technology in DoD logistics and detailed specific uses in the supply chain. DoD components were required to prepare a supporting implementation plan for the use of active RFID by 29 October 2004. DoD initially also required implementation plan for passive RFID by 29 October 2004, though this date was subsequently extended until the end of September 2005, then again until October 14, 2005, and finally to 18 November 2005. With the exception of DLA, which prepared separate implementation plans for active and passive RFID, DoD components chose to combine their treatment of the two types of RFID technology into a single plan. The last of these plans were delivered in November 2005, although some are still labelled as draft documents.

Implementation Plan Status	
Air Force	Draft
Army	Draft
Navy	Final
Marine Corps	Draft
DLA (active)	Final
DLA (passive)	Final
USTRANSCOM	Final
DeCA	Final

The different component implementation plans raised very similar issues and concerns. Some have already been resolved, as shown in Table 1. Technology demonstrations and pilot efforts that are being conducted will help to resolve the lack of data on initial implementations. In particular, these efforts should provide some data that are useful in helping to determine the resources needed for larger scale implementations. However, several issues remain. Most of these are addressed later in this section or in later sections of this report. Concerns relating to the integration of passive RFID technology into overall business processes and legacy AISs are beyond the scope of this report.

Table 1. Issues Raised in Implementation Plans

Issue/Concern ✓ = Resolved × = Outstanding – = Not raised	DoD CONOPS	Army	Navy	USAF	Marine Corps	DLA (Passive)	DLA (Active)	USTRANSCOM	DeCA
Finalize RFID policy and implementation strategies	–	✓	–	✓	✓	–	–	✓	–
Publish DFARS Rule for passive RFID tags	–	✓	–	✓	✓	✓	–	✓	–
Finalize the requirement for use of the EPC	–	✓	–	–	–	–	–	✓	–
Lack of migration strategy for passive implementation	–	×	–	×	×	–	–	–	–
Lack of metrics for determining success	×	×	×	×	–	–	–	–	–
Whether component budget requirements will be met	×	×	×	×	–	–	–	–	–
Funding for implementation in timeframe mandated	×	–	×	×	×	–	×	–	–
Lack of a comprehensive BCA for passive RFID	–	–	✓	×	×	✓	–	–	–
Lack of initial implementations validating performance	–	×	–	×	×	–	–	×	–
Lack of data for identifying the required resources	–	×	–	×	×	–	–	×	–
Finalize passive RFID technical specifications	–	✓	–	✓	–	–	–	✓	–
Ability to integrate with Service AISs	×	×	–	×	×	×	–	–	×
Integration of RF technologies into business processes managed with same attention as major system fielding	×	×	×	×	×	–	–	–	×
Lack of OSD education and training plan for passive RFID	–	×	×	×	×	–	–	–	–
Incompatible frequencies between CONUS & OCONUS	×	–	×	×	×	–	–	–	–
Poor performance within specific frequency bands	×	–	×	×	×	–	–	–	–
Widespread conformance to security/wireless protocols	×	–	×	–	–	–	–	–	–
Lack of HERO and HERF certification	×	×	×	×	×	×	–	×	–
Lack of communications/bandwidth for passive RFID	×	–	×	×	×	×	–	–	–
Ability to overcome technology challenges	×	–	×	×	×	–	–	–	×

To ensure integration and consistent operations, the Defense Logistics Board (DLB) will review the components' internal implementation plans, benefits, compliance, requirements, and requisite budget requirements annually based upon an assessment of the implementation to the time of each such review.

The Assistant Deputy Under Secretary of Defense for Supply Chain Integration (ADUSD(SCI)) initially planned to produce a synchronized internal DoD Implementation Plan based on component implementation plans. However, at the December 2005 DoD Automated Identification Technology (AIT) Integrated Product Team (IPT) meeting, it was announced that an O-6 level IPT consisting of an Office of the Secretary of Defense (OSD) lead, DLA, the Services, and USTRANSCOM would be established to synchronize the component plans [AIT IPT 2005]. This is a positive move since it allows the affected parties to be actively involved. However, it is uncertain whether synchronization of the plans will be sufficient to ensure a coherent architecture for the integrated use of active and passive RFID across the Services and DoD Agencies. Additionally, there do not appear to be established processes for coordinating RFID implementations with other ongoing DoD logistics transformation and business enterprise efforts.

DFARS

A DFARS provision added in September 2005 requires DoD suppliers to affix passive RFID tags to some goods shipped to DLA's Defense Distribution Centers (DDCs). The initial intent of ADUSC(SCI) was to develop a rule that applied to all new solicitations issued after 1 October 2004, for delivery of materiel on or after 1 January 2005. Although delayed, a new rule was published on 13 September 2005. Pending finalization of the new rule, DLA invited suppliers to volunteer to send RFID tagged material and associated Advance Shipping Notices (ASNs). Any agreement was strictly voluntary with no contractual obligation or compliance enforcement requirements. GE Aircraft Engines and Lockheed Martin both responded to this invitation.

Implementation Approaches

1. Market adoption with no DoD involvement
2. Market adoption with phased DoD involvement
3. Market adoption with immediate DoD implementation

One of the reasons for the delay in publishing the new rule was the need to perform an economic analysis, as required by Executive Order 12866, *Regulatory Planning and Review*. In March 2005, DoD published an Initial Regulatory Flexibility Analysis of Passive Radio Frequency Identification (RFID) [RFID 2005] that outlined three alternative RFID implementation approaches and their associated benefits, costs, and industry impacts. The analysis concluded that the most pragmatic option was for DoD to adopt a phased implementation approach. Accordingly, the 13 September 2005 addition to the DFARS only applies to cases and palletized units of operational rations, clothing, individual equipment, tools, personal demand items, and weapon system repair parts when these various items are shipped to Defense Distribution Depot, Susquehanna, PA (DDSP) or Defense Distribution Depot, San Joaquin, CA (DDJC). Further DFARS requirements will be needed to meet policy requirements for 2006 and 2007.

Standards compliance and efficiency are good reasons for a using a market-driven approach. However, such an approach may create risks that some DoD needs will not be met.

DoD Memoranda

On 30 August 2004, in accordance with the DoD RFID Policy, the Under Secretary of Defense (Acquisition, Technology & Logistics) (USD(AT&L)) issued a Defense Logistics Executive (DLE) Decision Memorandum that further clarified the implementation guidance contained in the Policy and redefined the implementation schedule for Electronic Product Code (EPC)-compliant passive RFID. It also directed DLA and the Deputy Under Secretary of Defense for Logistics and Materiel Readiness (DUSD(LM&R)) to determine the investment costs and benefits of implementation. This business case analysis (BCA) was needed to enable the DLB to assess the first year's progress, prior to follow-on implementation within the Services.

DLA Passive RFID BCA

Estimated net savings $69.9M to $1,781M in 2006-2011

Estimated break-even point ranges from immediately to 3 years out

A second DLE Decision Memorandum, issued on 10 March 2005, validated the findings of a passive RFID BCA prepared by the DLA Office of Operations Research and Resource Analysis (DORRA) [DORRA 2005] and directed the

Services to move forward with active and passive RFID implementation, but did not provide any additional funding guidance.

Other BCAs

In March 2004, DoD awarded a three-year contract to IBM Business Consulting Services to determine the business case, provide advice, and determine the success of the passive rollout as it moves forward. IBM undertook to take insights gleaned from RFID pilots that DoD had been running, and to help DoD draft a deployment plan. The plan was to have been ready by July 2004. The current status of this plan is unknown.

At the Service level, the Center for Naval Analyses (CNA) [CNA 2004] published a report on the costs and benefits of the Navy's adoption of passive RFID. It concluded that, between the technological uncertainties and the absence of hard information on large-scale benefits, any detailed cost-benefit analysis of RFID was premature. CNA also questioned DoD's proactive stance on RFID, cautioning on the risks of promoting an immature technology, one not yet proven in civilian business. In October 2004, the Army Science Board [2004] recommended that DoD and Army conduct a thorough business case and cost/benefit analysis for the use of RFID technology in the joint supply and transportation system prior to any further purchase, implementation, or reconfiguring of RFID. We were unable to determine whether any actions followed from this recommendation.

In a separate BCA, the Navy [NAVSUP 2005] estimated the potential return on investment (ROI) for the use of passive RFID technology ashore and afloat. The best case ashore estimates of ROI for the period 2005-2016 were a total cost of $70 million and a total benefit of $591 million, with a break-even point reached at between five and six years. Afloat, they found no evidence of achievable ROI on retrofit of the Fleet. The study recommended deferring major passive RFID investments until Program Objective Memorandum (POM) 08 and continuing to promote bar code applications.

The Army Logistics Transformation Agency (LTA) business process division is in the process of developing a BCA to determine where passive RFID best fits into Army logistics processes.

Active Tag Manager

The Policy specifies that DLA is the procurement activity and single manager for active RFID tags. Accordingly, DLA uses tags for its own business processes and issues them to other DoD components. The Policy encourages these components to return tags to DLA for refurbishment and reuse by providing packing, crating, handling, and transportation (PCH&T) reimbursement incentives, although components are permitted to establish their own procedures for reusing tags. Despite this incentive, DLA is receiving only about 3% of active tags back for potential reuse. Up to 30% are thought to be reused in theater, but the low rate of return for the remaining 70% may be due to the Army's use of a Single Stock Fund, which means that the financial benefit is not directly seen by the organizations that have to undertake the return processes [DLA, 2005].

A recent GAO report [2006] has recommended that the Secretary of Defense update the Policy, and other operational guidance, to require that active RFID tags be returned for reuse or be reused by the Services. DoD has agreed to issue such guidance by July 2006. DoD only partially concurred with a second GAO recommendation to direct the secretaries of each Service and administrators of other components to establish procedures to track and monitor the use of active RFID tags. DoD will task the Services and USTRANSCOM to develop appropriate procedures for return and reuse by July 2006. However, DoD regards active tags as consumable items and procedures to account for their procurement, inventory, repair, and loss as unnecessary.

Other GAO Recommendations and Issues

The 2005 GAO report [GAO 2005] on DoD's implementation of passive RFID found that it lacked a comprehensive strategic management approach and was missing several key management principles.

Recommendations

The GAO made three recommendations:

1. USD(AT&L) should expand current RFID planning efforts to include a DoD-wide comprehensive strategic management approach to ensure efficient and effective implementation. OSD did not concur, asserting that it had already set forth goals, objectives, performance measures, and milestones sufficient to guide the planning activities of the military services, DLA, and USTRANSCOM, and that these activities had plans in development. Moreover, OSD is not the program office for RFID implementation. It is expected that the AIT IPT's planned synchronization of component implementation plans will resolve this concern.
2. Secretaries of each military service, and administrators of other military components, should develop individual comprehensive strategic management approaches that support the DoD-wide approach for fully implementing RFID into the supply chain processes. OSD concurred with this recommendation. It has since been met with the delivery of the component implementation plans.
3. USD (AT&L), the secretaries of each military service, and administrators of other military components should develop a plan that identifies the specific challenges impeding passive RFID implementation and actions needed to mitigate these challenges. OSD did not concur, stating that the challenges have either already been mitigated or they represent a misunderstanding of the technology and its implementation in the Department.

GAO: Missing Principles

- General/long-term goals and objectives
- Descriptions of actions to support goals
- Performance measures to evaluate actions
- Schedules/milestones to meet deadlines
- Resource/costing estimates
- Program evaluation with adjustment processes

Resolved Issues

The GAO report also identified several other issues. Most of these have been resolved, as indicated in Table 2. In July 2005, EPCglobal announced that its EPC tag data standard had been revised to incorporate DoD's Commercial and Government Entity (CAGE) code and the DoD Activity Address Code (DODAAC), that are used by DoD suppliers to identify shipments. As previously mentioned, the new DFARS rule was finalized on 13 September 2005. All five Blanket Purchase Agreements have now been awarded. As of December 2005, all the components had delivered their implementation plans. The Assistant Deputy Under Secretary of Defense (ADUSD) SCI established a formal agreement with the Procurement Technical Assistance Centers (PTACs) to provide RFID training and outreach to the DoD supplier community. They also developed "Train-the-Trainer" material that has been presented at fourteen regional sites. Although the International Organization for Standards (ISO) ratification of the EPC Class 1 Gen 2 standard has not occurred yet, this is expected in March or April of 2006.

Many organizations from OSD, the Joint Staff, the Services, and the Combatant Commands are involved in the implementation of RFID. Effective communications are thus paramount to successful implementation of the Policy. As the DoD CONOPS for RFID says, "continued partnership with each of the

IWG Mission

Plan migration and provide implementation planning and oversight
Ensure compatibility with private sector
Be *last group standing*—for full DoD RFID implementation and migration

Table 2. Status on Issues Raised in GAO Report [2005]

Issue	Resolved
EPC standards need revision to accommodate DoD data [p. 5]	✓
DFARS for passive RFID had not been finalized [p. 31]	✓
2 (of 5) blanket purchase agreements remain to be established [p. 33]	✓
Lack of component implementation plans for passive RFID [p. 13]	✓
Need for IPTs to address issues [p. 14]	✓
Lack of a worldwide frequency standard for passive RFID tags [p. 28]	No
EPC Gen 2 standards have not been approved by ISO [p. 25]	Expected
Training is an ongoing challenge to passive RFID implementation [p. 26]	✓
Interoperability systems and standards need to be established [p. 27]	Partial

BPWG Mission

Analyze and identify DoD logistics processes
Make recommendations for process re-engineering
Identify optimal RFID technologies for each Supply Chain process

TWG Mission

Identify and develop:
Technical Specifications
Standards
Identify appropriate RFID technologies for the DoD supply chain

Services and Agencies is critical to the success of this initiative" [CONOPS 2004]. At the 22 to 23 October 2003 RFID IPT Kickoff Meeting, three IPT working groups were formed: (1) the Technical Working Group (TWG), (2) the Business Process Working Group (BPWG), and the Implementation Development and Oversight Working Group (IWG). DLA has representatives on all these groups. These WGs were to have met at least bi-monthly. After a hiatus of two years, the IWG has recently started meetings. In addition, a DLA IPT meets weekly and the DoD Logistics–Automatic Identification Technology (LOG-AIT) Office hosts a periodic "breakfast club" on active RFID. USTRANSCOM conducts monthly teleconferences on RFID implementation issues. These activities would seem to go a long way towards meeting GAO concerns about management coordination.

The outstanding issues relate to the lack of global passive RFID frequency standards (discussed later in this Section), and systems interoperability and standards.

Interoperability

A complete discussion on interoperability is beyond the scope of this report. However, it is important to mention that the OUSD(L&MR), Logistics System Management (L/LSM) memorandum, 17 March 2000, *Execution Guidance for Joint Total Asset Visibility (JTAV)*, directed the sunset of the JTAV capability by the end of FY 2005. Additional guidance directed that the Integrated Data Environment (IDE) subsume the functional capabilities and data requirements provided by the JTAV capability. The principal benefit of the IDE is the reduction of the number of system-to-system data interfaces and the operational cost associated with these interfaces. In the interim, the distributed Defense Logistics Management System (DLMS) bridge enables non-DLMS (legacy) systems to handle RFID data by providing an interface that translates RFID data into a form accepted by those systems.

Other Issues

There are a number of additional issues that will impact the implementation of RFID technology. While some of these may not have a direct impact on DLA, they will have an indirect effect through their impact on DLA's partners in the DoD supply chain.

Funding

The Policy states that the cost of implementing and operating RFID technology is considered a normal cost of transportation and logistics, and as such should be funded through routine Operations and Maintenance or Working Capital Fund processes. In the case of active RFID, it is the responsibility of the activity at which containers, consolidated shipments, unit move items, or air pallets are built or reconfigured to procure and operate sufficient quantities of RFID equipment to support these operations. Working Capital Fund activities providing this support should use the most current DoD guidance in determining whether operating cost authority or capital investment program authority will be used to procure the required RFID equipment. If the originating activity of a Layer 4 container or consolidated air pallet is a vendor location, it is the responsibility of the procuring Service or Agency to arrange for the vendor to apply active tags, either by obtaining sufficient RFID equipment to provide the vendor with the capability or requiring the vendor to obtain necessary equipment as a term of the contract. Additionally, Combatant Commanders (COCOMs) are responsible for coordinating with their Service components to ensure the availability of RFID infrastructure at key logistics nodes. This means that the COCOMs, who most directly benefit from the use of active tagging, set requirements that must be met by the Services out of their own funding.

Much of the funding issue is a result of the POM cycle. Without prior notice of the RFID requirement, before the Policy was issued the Services had not included funding for RFID implementation in their previous planning and budgeting for Fiscal Years (FY)06 through FY11. Consequently, a 28 July 2004 RFID DLB Decision Brief [DLB 2004] estimated a $168.7 million shortfall over the POM period 2006-2011 for Active RFID Implementation (see Table 3). Although DLA itself does not expect to incur any shortfall, the value of DLA's tagging efforts will be severely eroded if other participants in the supply chain are unable to read and write active tag data.

In the case of passive RFID, it is the responsibility of the DoD activity at which cases or palletized unit loads are built to procure and operate sufficient quantities of passive RFID equipment to support required operations. It is the responsibility of the activity at which cases or palletized unit loads are received, that is, the activity where the supply receipt is processed, to procure and operate sufficient quantities of passive RFID equipment to support receiving operations. Again, Working Capital Fund activities providing this support will use the most current DoD guidance in determining whether operating cost authority or capital investment program authority will be used to procure the necessary RFID equipment.

The July 2004 DLB Decision Brief estimated the costs of passive RFID internal implementation at $104.4 million for the first three years, as illustrated in Table 4.

Table 3. Active RFID Implementation Cost Estimates (in $1,000s)

	2006	2007	2008	2009	2010	2011	Total
DLA	$50	$43	$43	$150	$200	$200	$686
POM	$50	$43	$43	$150	$200	$200	$686
Difference	$0	$0	$0	$0	$0	$0	$0
USTC	$16,000	$13,200	$13,200	$13,200	$13,200	$13,200	$82,000
POM	$0	$0	$0	$0	$0	$0	$0
Difference	-$16,000	-$13,200	-$13,200	-$13,200	-$13,200	-$13,200	-$82,000
USA	$111,700	$100,600	$107,070	$106,040	$106,040	$106,040	$637,490
POM	$110,700	$100,600	$107,070	$106,040	$106,040	$106,040	$636,490
Difference	-$1,000	$0	$0	$0	$0	$0	-$1,000
USN	$6,160	$720	$720	$720	$720	$720	$9,760
POM	$0	$0	$0	$0	$0	$0	$0
Difference	-$6,160	-$720	-$720	-$720	-$720	-$720	-$9,760
USMC	$5,500	$8,060	$8,060	$8,060	$8,060	$8,060	$45,800
POM	$0	$0	$0	$0	$0	$0	$0
Difference	-$5,500	-$8,060	-$8,060	-$8,060	-$8,060	-$8,060	-$45,800
USAF	$5,700	$4,900	$4,900	$4,900	$4,900	$4,900	$30,200
POM	$0	$0	$0	$0	$0	$0	$0
Difference	-$5,700	-$4,900	-$4,900	-$4,900	-$4,900	-$4,900	-$30,200
Total	$145,110	$127,523	$133,993	$133,070	$133,070	$133,070	$805,936
POM	$110,750	$100,643	$107,113	$106,190	$106,190	$106,190	$637,176
Difference	-$34,360	-$26,880	-$26,880	-$26,880	-$26,880	-$26,880	-$168,760

In this approach to funding the implementation of passive RFID technology, 65% of the costs are Working Capital Funded. The danger in requiring the Services to cover the costs (as opposed to a line item at the DoD level) is that their funding can be cut in face of more pressing demands and it is clear from the Service implementation plans that they consider the RFID policy to be an unfunded mandate. Additionally, the absence of BCA and ROI data could make it difficult for the Services to get funds approval. It is also important to note that the current DLB plan covers only RFID-enabled shipping and receiving processes for strategic distribution, transportation, and maintenance nodes. Extending the uses of RFID data to facilitate logistics decision-making is planned for FY07 and beyond.

In the recent POM cycle, the Deputy Secretary of Defense issued a Program Decision Memorandum on 22 December 2004 that included the following requirements:

1. Joint Staff (J4) and USD AT&L will co-lead a team to establish metrics for monitoring and assessing the progress of active RFID technology implementation and the impact of RFID on the Services second destination transportation accounts.
2. USD(AT&L), in collaboration with USTRANSCOM, Joint Staff (J4), Navy, and USAF will provide to the DLB by 31 March 2005 a strategy for synchronizing DoD's RFID investments. [USTRANSCOM 2005a]

The status of these actions is unknown.

Table 4. Passive RFID Implementation Cost Estimates (in $1,000s)

	2005	2006	2007
DLA	San Joaquin, Susquehanna, Oklahoma City $5,109	Albany, Anniston, Barstow, Cherry Point, Columbus, Corpus Christi, Hill, Jacksonville, Norfolk, Oklahoma City, Puget Sound, Red River, Richmond, San Diego, Tobyhanna, Warner Robins $16,915	Germersheim, Sigonella, Bahrain, Pearl Harbor, Guam, Korea, Yokosuka $7,164
USTC	Dover, Ramstein $0	Travis, Charleston, Norfolk $4,111	Yokota, Major Ports (8) 1 testing facility (Scott), 3 training facilities (Ft Dix, Lackland, Dobbins) $12,354
USA	Kaiserslautern $0	Red River, Anniston, Corpus Christi, Tobyhanna $4,974	Ft Hood CRP, Ft Bragg CRP, Ft Campbell CRP $3,502
USN	Norfolk Ocean Terminal $0	NADEP Cherry Point, NADEP JAX, NADEP North Island $7,411	Norfolk NSY, Portsmouth NSY, Puget Sound NSY, Pearl Harbor NSY $7,316
USMC	MCB Lejeune $0	MCB Lejeune (deployable portals) Blount Island Command, MCB Pendleton TMO/SMU, MAGTFTC 29 Palms $9,014	MCAS Miramar, MCAS Yuma, MCAS Beaufort, MCAS Kaneohe Bay $10,952
USAF	Seymour Johnson, Charleston, Dover, Ramstein, Spangdahlem $0	Oklahoma ALC, Warner Robins ALC, Ogden ALC $3,646	Read/Write capability at 10 TMOs, Print Capability at 75 TMOs $11,977
Annual Total	$5,109	$46,071	$53,265
Overall Total	$104,400		

Another important point is that most cost estimates are based on assumptions that passive Ultra High Frequency (UHF) RFID tags will decline in costs over the next several years. There is some risk that these assumptions may not be met.

Spectrum Management As the Army RFID Implementation Plan [Army 2004] observes, spectrum management issues need to be resolved to support frequency allocation for global use of RFID. Even though there is international agreement on frequency usage for active RFID, and High Frequency (HF) passive RFID, an organization needs to obtain frequency supportability and frequency assignment before it can operate an RFID device in a foreign country. Experience with military peacetime operations has shown this can take up a year or more for Outside the Continental United States (OCONUS).

There are no international agreements on frequency allocation for passive UHF RFID. Additionally, countries handle licensing in different ways. In some countries, like the U.S. and Europe, UHF can be used without a license for certain frequencies, but there are restrictions on the transmission power that can be used. There is no general regulation of UHF in Japan and China; instead every application needs a site license.

The U.S. and Canada use a 915 MHz UHF frequency for passive RFID. Following a decision by the forty-six national communications authorities in September 2004, the European Community Council (ECC) adopted a frequency range from 865 to 868 MHz for passive RFID readers, with different power levels permitted for specific frequencies within this range. Starting in 2005, passive tags were allocated from 952 to 954 MHz in Japan. These international differences are not easy to resolve because frequency spectrums are heavily utilized in many countries. The 915 MHz frequency, for example, is used in Europe for cellular telephone service.

Frequencies and power levels have implications for RFID performance. Lower frequencies have lower data rates because of bandwidth limitations. Power level, lower in Europe than in the U.S., influences tag read range and limits the ability to frequency hop, resulting in less reliable tag visibility and read reliability. DoD needs to know more about the practical consequences of the limitations imposed by particular countries.

The U.S. Government is looking to industry to promote RFID frequency harmonization by developing standards. Meanwhile, DoD is mitigating the problem to some extent by requiring passive RFID systems to operate in the 860 to 960 MHz range.

Privacy, safety, and security Privacy, safety, and security are all regulatory issues. Privacy is not an issue for the use of RFID in the DoD supply chain, although DoD may experience higher RFID costs resulting from manufacturers' need to respond to the increasing push for laws regulating RFID privacy in the private sector. Security is not addressed here in any depth, but it is worth noting that the pertinent security regulation is Federal Information Processing Standards (FIPS)-140, Security Requirements for Cryptographic Modules. FIPS encryption is not available on current Class 0 and Class 1 passive tags. The Product Manager, Joint-Automatic Identification Technology (PM J-AIT) Radio Frequency–In-transit Visibility (RF-ITV) End-to-End Security Architecture Working Group has been established to look at the development of secure tags for late 2007 or early 2008.

One of the main safety issues is the possible effect of stray electromagnetic radiation from RFID tags, readers, antennas, and power sources. The *DoD Suppliers' Passive RFID Information Guide* [Supplier 2005] specifies that munitions and explosives shall not be tagged with passive RFID tags until Electromagnetic Effects on the Environment (E3), and Hazardous Electromagnetic Radiation to Ordnance (HERO) certification requirements have been met. Hazardous Electromagnetic Radiation on Personnel (HERP) and Hazardous Electromagnetic Radiation on Fuels (HERF) are also concerns. The RFID Policy mentions that U.S. and OCONUS host nations' spectrum management policies may also require HERF assessment.

Compliance with E3 requirements ensures mutual electromagnetic compatibility and effective E3 control among ground, air, sea and space-based electronic and electrical systems, subsystems and equipment, and with the existing natural and man-made electromagnetic environment. DoD Directive (DoDD) 3222.3, DoD

Electromagnetic Environmental Effects (E3) Program, outlines the policy and responsibilities for the management and implementation of the DoD E3 Program. Military Standard (MIL-STD) 461, Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment, documents the EMI requirements for a wide range of applications, from trucks to ships to aircraft to fixed installations. Finally, DD Form 1494, Application for Equipment Frequency Allocation, must be completed for all systems and equipment that emit or receive Hertzian waves.

DoD is reexamining the question of whether its active 433 MHz RFID systems may, under certain circumstances, interfere with radar equipment. The National Telecommunications and Information Administration first raised this concern in 2002 when the Federal Communications Commission (FCC) reviewed spectrum use for Savi's 433 MHz RFID system. As a consequence, in April 2004, the FCC issued new regulations for RFID systems in the 433 MHz band that mandated certain precautions, including narrowing the 433 MHz RFID frequency band from 433.5 to 434.5 MHz and forbidding RFID readers from being deployed within 25 miles of five specified U.S. radar sites that operate in the 420 to 450 MHz frequency band. The Joint Staff Director of Command, Control, Communications, and Computer Systems also addressed the issue of interference with radar systems recently, based on the results of a test performed early in 2005. It is likely that more testing will be conducted looking at these risks.

Radar Using 420-450 MHz
Beale Air Force Base
Cape Cod Air Force Station
Cavalier Air Force Station
Clear Air Force Station
Eglin Air Force Base

DoD has completed extensive testing of the specific active RFID technology (fixed readers, hand-held readers, radio frequency (RF) relays, RFID tags) used by DoD today. The DUSD(L&MR) has published detailed guidelines for its safe use around munitions, fuels, and personnel. In addition, there are DoD Directives (DoDDs) that address these areas. Those for HERO are DoDD 6055.9-E, Explosives Safety Management and DoD Explosives Safety Board, and DoDD 6055.9-STD, DoD Ammunition and Explosives Safety Standards. Exposure of people to electromagnetic radiation is covered in DoD Instruction (DoDI) 6055.11, Protection of DoD Personnel from Exposure to Radio frequency Radiation and Military Exempt Lasers.

In a more general activity, the Army Field Support Command and Joint Munitions Command are assessing the future logistics capability for using passive and active RFID around ordnance. The passive RFID assessment began October 2004 and was to be completed by September 2005.

3. DoD's New Uses of Active RFID

ACTDs Initiated In FY06

- Event Management Framework
- Extended Space Sensors Architecture
- Joint Enable Theater Access
- Multi-Service Advanced Sensors to Counter Obscured Targets
- Node Management and Deployable Depot
- Small Unmanned Air Vehicle

DoD has used active RFID technology for sustainment cargo ITV for many years. The experience gained in Foal Eagle 99, Freedom Banner–Cobra Gold 2002, Operation Joint Endeavor, Operation Iraqi Freedom, and Operation Enduring Freedom has been well documented. Components' practices seem to be mature, even though the relevant CONOPS and Implementation Plans have only recently been developed. Some other applications of active RFID technology are also mature. The RFID capability developed in the USAF Afloat Prepositioned Fleet AIT Initiative has been used since 2001 to manage the movement and stuffing of assets in the Afloat Prepositioned Fleet and to facilitate ITV of deployed prepositioned containers. Similarly, active RFID has been in operational use tracking parts at the Ring Gyro Shop at Robins Air Logistics Center since 2003.

This section discusses Advanced Concept Technology Demonstrations (ACTDs) that include active RFID technology and non-ITV DoD uses of the technology. For the latter, it discusses technology demonstrations and pilot efforts, both recently completed, underway, and planned. Figure 1 illustrates how this sample set of active RFID technology efforts maps across DoD supply chain nodes.

ACTDs

ACTDs are used to expedite the transition of maturing technologies from the developers to the users. They emphasize technology assessment and integration rather than technology development. The goal is to provide a prototype capability to the warfighter who can evaluate the capabilities in real military exercises and at a scale sufficient to fully assess military utility. An ACTD concludes with a Military Utility Assessment (MUA). The DUSD, Advanced Systems & Concepts, has oversight responsibility for the ACTD program, which includes developing guidance, evaluating candidates and approving new ACTDs, and oversight, support, and evaluation of ongoing ACTDs.

ATOS

The Advanced Technology Ordnance Surveillance (ATOS) ACTD combined active RFID technology with sensor technology. It was designed to meet Joint Vision 2020 and CINC-29 Warfighter Requirements for the Global Combat Support System (#11), a Category One requirement for "accurate and actionable total asset visibility." More specifically, the system provides supply managers with the ability to accurately locate and continuously determine the status of individual munitions on a near-real-time basis, while also updating predictions of the future condition and performance of munitions. These capabilities are intended to support service-life prediction, informed decisions for asset disposition, proactive acquisition, and shelf-life management of munitions. The system uses active RFID tags augmented with sensors for temperature, humidity, and shock.

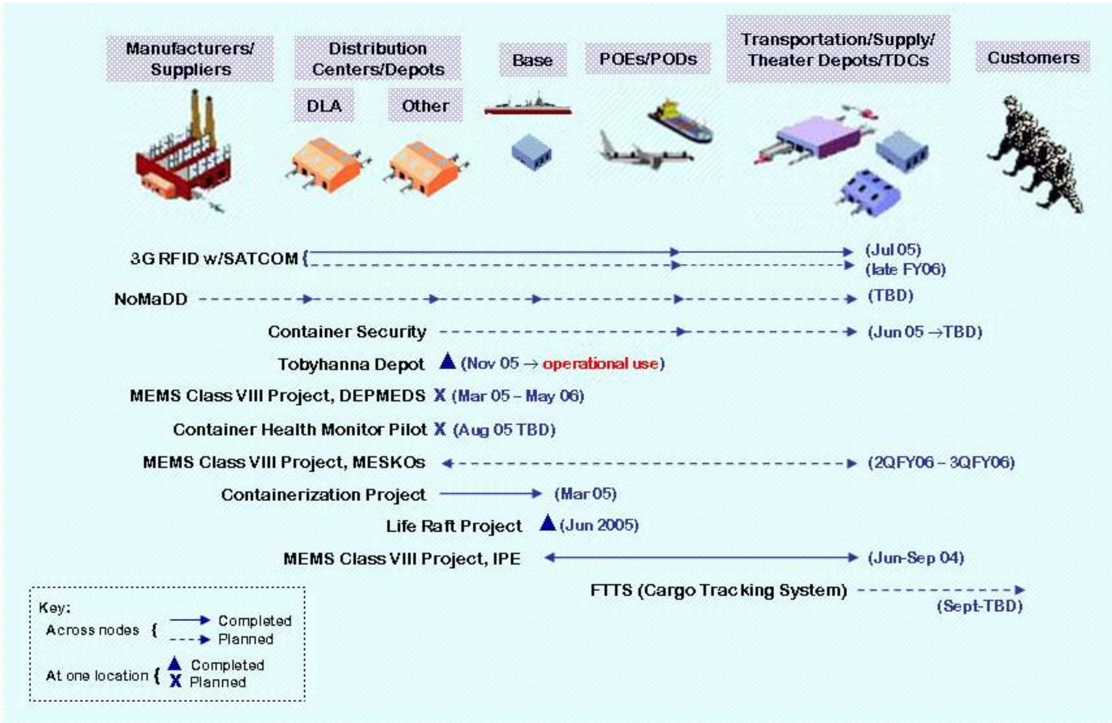


Figure 1. Active RFID Coverage of Supply Chain Nodes

Military Utility Assessment Ratings

- Demonstrated utility, deployable now, recommend minor improvements
- Potential utility, recommend minor improvements
- Potential utility, requires major improvements
- No utility demonstrated, complete redesign needed
- Insufficient data or not assessed

ATOS defined a set of minimum requirements that any DoD RFID system should meet in order to operate safely in any environment. The requirements for environmental monitoring and surveillance include external sensor ports that can accommodate all capacitive type sensors, the ability to set environmental alarms and alerts for user-defined environmental extremes, and access to environmental 'snapshots' through AISs and readers. Requirements for portable readers to provide validations of all transactions and dead battery revival that allows for tag data retrieval from a 'dead' battery assure reliable operation. User access and authorization levels for portable readers help security issues. A memory map of all data elements supports the ability to interface with Military Standard Requisitions and Issue Procedures (MILSTRIP) and Military Standard Requisitions and Accounting Procedures (MILSTRAP) AISs. The system is also HERO certified. Finally, the requirements for system supportability include backward and forward read capabilities for a variety of AIT devices, fixed readers capable of being powered by any 24V source, independence of an RFID infrastructure, and a non-proprietary, open-source architecture.

ATOS completed a 4-year ACTD in FY05 under the sponsorship of U.S. European Command (USEUCOM). As part of the MUA, full-system demonstrations were conducted at retail, wholesale, and maritime facilities at the Naval Sea Systems Command (NAVSEA) Naval Surface Warfare Center (NSWC), Indian Head Division; Miesau, Germany; NSWC Division, Crane, IN; and onboard USS Truman. The MUA rated the ATOS environment surveillance capability as having Potential Utility (with minor recommended improvements), and the ratings for examined elements of the munitions management capability ranged from Demonstrated Utility to Potential Utility (with major improvements required). The system's training, power, and installation capability also received the highest level of rating. USEUCOM's recommendation was to add the ATOS capability to DoD's inventory. All MUA recommended changes were expected to be completed by the end of 2005.

An ROI calculated for the Navy estimates that ATOS can save 373 sailor work-years annually, and provide an annual cost savings or cost avoidance of $41.4M. Particular incidents may increase the benefit. When four of thirty-two Patriot missiles were dropped several feet in Operation Iraqi Freedom, the inability to assess potential damage to internal missile components resulted in all 32 missiles being taken out of service at an incurred cost of $21.9M, without accounting for man-power, handling, and shipping [NAVSEA 2005]. NAVSEA cited this incident as an example where the data provided by ATOS could have resulted in large cost savings.

The Navy is currently seeking funds to implement ATOS at four key sites (one in each Service) and to conduct further demonstrations. Future work would also look at extending the flexibility of external sensor data ports to accommodate any type of sensor, including sensor networks; improving power management algorithms and tools; reducing the active tag footprint and profile; including environment models and algorithms; and embedding RFID in munitions. Other ongoing work is investigating the use of the ATOS tag for medical applications at Sierra Army Depot and for toxic chemical applications.

A one-day event conducted at the Sierra Army Depot in November 2004 demonstrated the association of passive tags to active tags. In a simulated supply chain, packages of medical materials were configured into medical kits. These kits were then moved into storage, prepared for shipment by commissioning environmental tracking passive tags, and shipped to an OCONUS site where the kit was received at a Theater Distribution Center (TDC). In this demonstration, item- and shipment-level data were exploited in a business enterprise system used to manage inventory and associated financial records.

NoMaDD

DLA initiated the Node Management and Deployable Depot (NoMaDD) ACTD in September 2004. This is a 3-year demonstration that commenced in early FY06. The objective is to provide DoD components with logistical information management and physical materiel handling capability that enables responsive and manageable flow of materiel into any theater, from the source of supply through to the tactical supply activities. NoMaDD plans to use an expanded version of the Army's Battle Command Sustainment Support System (BCS3) for node management. This will provide the ability to manage the supply pipeline by exception, establishing monitoring parameters that trigger alerts when exceeded. Active RFID technology will be used to provide the necessary ITV data.

NoMaDD also includes a Deployable Depot that will provide theater control over supplies inbound to an Area of Responsibility. The capability will include deployable warehousing structures, a materiel handling infrastructure, connected AISs, and a trained workforce for COCOMs and DoD. It is being designed so that a Deployable Depot can be quickly stood up as a TDC or a Depot. The role of RFID technology in the Deployable Depot is still being determined, but is likely to include passive RFID.

Before completion of the ACTD, both components of NoMaDD will undergo a Joint MUA within a large-scale military field exercise involving joint supply distribution, such as COBRA GOLD or TALISMAN SABER.

FTTS RFID technology also plays a role in the Future Tactical Truck System (FTTS) ACTD initiated in 2004. The objective of this ACTD is to substantially reduce the battlefield footprint by providing fuel-efficient, self-supporting, and interoperable maneuver sustainment and utility vehicles. The Maneuever Sustainment Vehicle (MSV) is a heavy payload variant of the FTTS that has an RFID reader to interrogate active tags attached to loaded cargo, automatically transmitting data such as where it was picked up to a logistics AIS. The reader will connect with the military tactical air network, using either ground-based or satellite communications. Two prototype MSVs are scheduled to be delivered in May 2006. These will be used for testing in Army operation simulations at Fort Lewis, WA, expected to start in September. The RFID capability will allow ITV of supplies into a theater of operations, allowing on-demand locating of supplies across the last link in the supply chain. The tag will be used to provide commodity information only, supporting geospatial positioning data will be acquired using military communications.

Pilots and Demonstrations

The type of active RFID technology in DoD operational use for ITV purposes has remained largely unchanged over the last decade. There are several efforts underway that demonstrate additional uses of the technology or extensions to the base technology.

Containerization Project The Naval Facilities Expeditionary Logistics Center (NFELC) is engaged in a pilot effort in which active tags are being used to: (1) allow deployed personnel with handheld readers to determine container contents without having to open the container, and (2) manage container inventory. These tags are not currently used for ITV purposes.

The NFELC is responsible for assembling, preparing, packing, and sustaining all equipment comprising a Table of Allowance (TOA) for deployed Naval Construction Forces that provide theater combat Level III construction and contingency support. Consequently, personnel must be able to access container manifest data on the RFID tag in the absence of an existing on-site RFID infrastructure in order to permit effective staging and use of assets. TOAs may be aboard Military Sealift Command Maritime Pre-Positioning Force (MPF) ships, at ports of embarkation, or loaded onto air transport pallets for shipment to deployed sites. Consequently, the project is examining permanently attaching active tags to containers and treating the tag itself as part of the TOA. This is intended to reduce the time and resources needed to locate containers and conduct the mandatory, bi-annual container inventory.

In the pilot, 600 active tags were attached to containers at the Naval Construction Battalion Center, Gulfport, MS. Containers were tracked from receipt to build-up to storage. A demonstration with pre-staged containers was conducted in March 2005 using 47 containers recently shipped to the USS Wheat. The pilot also demonstrated the use of the technology for a biennial container inventory. The system is currently in operational use at Gulfport, MS, and Port Hueneme, CA.

A follow-on effort is expected is extend the capability to include Civil Engineering Support Equipment and Civil Engineer End Items for MPF operations. In early- to mid-2006, it will also start capturing transportation data and transmitting this to the RF-ITV server, as well as investigating the possibility of providing maintenance data, such as allowance parts lists, on the active tags.

Container Security A new generation of active tags that promote container security are coming to market. These tags are augmented with sensors that can detect and report when a container door is opened. The Savi ST-676 uses a door sensor and light sensor to detect security breaches (in addition to other sensors that can monitor environmental conditions inside the container), and the E.J. Brooks E-Seal is a single-use, RFID-enabled electronic container bolt seal. Both these tags were successfully tested in recent transpacific field trials. The Savi container security tag was examined in another demonstration conducted from July 2002 to June 2003. Sixty-five companies participated, with more than 800 containers being tracked across eighteen different trade lanes, from three overseas ports to the U.S. Seattle-Tacoma port. In the U.S., the Department of Transportation and the Bureau of Customs and Border Protection are just two of the groups interested in this technology but, unlike DoD, their concern is with imports into the country. DoD is concerned with both outbound and inbound shipments as major units are deployed and rotated among stations.

The Army's Natick Soldier Center Combat Feeding Directorate is one of several groups participating in a forthcoming demonstration using container security tags from several vendors. Likely to start before June this year, this demonstration will last for three to four months. The supplies will be non-refrigerated Line Item A rations and they will be shipped to a prime vendor warehouse on station in the Persian Gulf. The objectives of the demonstration will be to identify where this technology is best suited for the way DoD supplies are handled and to identify any technology gaps. It will use at least 100 containers, requiring two or three ships for transportation.

3G RFID w/SATCOM The Third Generation RFID with Satellite Communications effort examined the feasibility of transmitting RFID reader data directly to the Iridium network of satellites, negating the need for a land-based RFID infrastructure. In a Phase I proof-of-concept trial, pallets tagged with a prototype tag that incorporated a Global Positioning System and satellite communication capability were shipped from DDSP to Kuwait; Tikrit, Iraq; Kosovo and Bosnia; or Kandahar, Afghanistan. ITV data was sent via satellite to several systems, including the Global Transportation Network.

Although the demonstration was technically successful, the cost of relying on satellite communications was deemed too high. For example, monitoring 750,000 tags transmitting six reports a day, at a cost of $0.08 a report, would total $3,600 a day. Consequently, the second phase of this work (now called Next Generation RFID with Wireless Communications) is looking to add wireless capabilities to the tag in an effect to reduce life cycle management costs. This exploration is considering cellular, 802.11, 802.16, and Ultra Wide Band (UWB) technologies. A demonstration of a new prototype is expected later in FY06.

MEMS Class VIII The Army LTA is working with active RFID technology and micro-electro-mechanical systems (MEMS) to provide proactive logistics that will support mission readiness. An initial proof of concept pilot was conducted using

Individual Protective Equipment (IPE) assets. Using RFID tags incorporating MEMS temperature sensors, over 100 pallets of IPE assets were monitored during storage at the Blue Grass Army Depot, KY, in transit, held at a desert destination in Iraq (outside in open storage, then outside in covered storage, and then in a climate-controlled warehouse), and in recovery operations at Pine Bluff Arsenal, AR. In addition to demonstrating the use of the technology for asset shelf-life management and visibility, this pilot provided data that is being used to help determine the effects of a harsh temperature environment on IPE assets. For example, it is supporting controlled laboratory testing to identify the required trigger thresholds for temperature alerts for this type of asset. Also, an interface is being developed for the Mobility Inventory Control Accountability System to allow the system's IPE shelf-life management tool to use the MEMS data.

Two subsequent demonstrations are both focusing on medical supplies. The first of these is using sensor-enabled RFID tags for medical supplies in the Deployable Medical Systems long-term storage at Sierra Army Depot. Tags are attached to containers selected for the demonstration by the U.S. Army Medical Materiel Agency in conjunction with the requirements for its Medical Reengineering Initiative. The data collection is expected to conclude in May 2006. The second demonstration with medical supplies will start in the second quarter of FY06. It will use the MEMS-enabled tags to support the assembly, transportation, receipt, and subsequent retrograde of Medical Sets Kits and Outfits (MESKOs). These will be assembled and shipped from the U.S. Army Medical Materiel Center–Europe (USAMMCE), Pirmasens, Germany, to a consignee location in Qatar in the third quarter of FY06. MESKOs were selected for this demonstration because they represent combinations of nearly every other kind of Class VIII medical product, and so most issues that may occur are likely to be encountered, as well as all potential benefits. The MEMS-enabled RFID tags will be used for location and health monitoring of the supplies, using temperature, humidity, and shock sensors for the latter. The potential value of this capability is evident from past incidents, such as the case in which USAMMCE had to destroy over $2.1M of MESKO materials due to the possible effects of unknown environmental conditions.

Container Health Monitoring The V-22 Fleet Support Team was the one of the first DoD organizations to use active tags with sensors. In 2003, the condition inside containers of aircraft engines and engine modules could only be assessed using humidity indicators and view ports. It was not desirable to open a container to assess conditions since this was a costly process and ran the risk of a container being resealed improperly. Marines had to manually check the engine containers every 28 days on land, and at least every 14 days when deployed aboard ships, or in other harsh environments. The system that was developed used temperature and humidity sensors tied into active RFID tags to report container conditions and send alerts when thresholds were breached. This system, the Naval Aviation V-22 Container Health Monitoring System (CHMS), is noteworthy in that not all containers are interrogated. Instead, CHMS uses an RFID sensor network in which tags pass information from one to another until the data reaches the last container in the network. Only this last container communicates with an RFID reader. This approach allows reducing the reader and wired network infrastructure by enabling containers to be monitored even when some are not close to a reader.

CHMS was successfully tested in a six-month, proof-of-concept trial and is now in operational use at the Marine Corps Air Station, New River, NC.

In its current version, the CHMS is a closed-loop system, with environmental data only being transmitted locally to a custodian. Work is underway to extend the system to monitor container movements. The necessary site surveys have been completed in Jacksonville, FL, and the RFID infrastructure is expected to be completed by early fall 2006. The new system will use a commercial tag that can monitor temperature and humidity and communicate with DoD's ITV network.

Tobyhanna Depot

Tobyhanna Army Maintenance Depot, the largest full-service electronics maintenance facility in DoD, recently completed a pilot use of active RFID technology for asset management. This effort is particularly interesting because it is supported by a detailed comparison of the cost of implementing the RFID system and net benefits associated with the improved process flow resulting from the use of RFID technology.

AN/TPS-75

Average Direct Hours
16% decrease
Average Labor Cost
8% decrease
Average Total Cost
8% decrease
Average Cycle Time
35% decrease

AN/TRC-170

Average Direct Hours
1% increase
Average Labor Cost
3% decrease
Average Total Cost
3% increase
Average Cycle Time
8% decrease

The pilot tracked AN/TPS-75 and AN/TRC-170 radar and microwave communication systems through the overhaul and repair maintenance process. The AN/TRC-170 is an example of the complexity of the process: "The average system breaks down into approximately 25-30 disassembled parts with each traveling to three or four support shops. When combined with the occasional part that requires rework or fabrication, there are approximately 120 traceable actions […]" [NPC 2005]. This process can take 12 to 15 months to complete. In the pilot, groups of a subset of parts were tagged for each of an AN/TPS-75 and AN/TRC-170 system. Their arrival and departure at each work area was recorded, allowing alerts to be sent when parts remained stationary longer than the allotted time, and provided data that could be used to analyze work-in-process flow and prevent bottlenecks in the process. The RFID system covers nearly 1,000,000 square feet and provides a graphical representation of part locations.

The expenses incurred in actual overhaul and repair activities, and most of the associated labor, are independent of the use of RFID, making cost comparisons difficult. The ROI calculation assumed that only 30% of the observed benefits were actually related to the use of the technology. Accordingly, based on the average processing of five AN/TPS-75 and sixty-six AN/TRC-170 systems a year, the costs of the pilot would be recouped in around eleven months of operational use. Perhaps more to the point, from the warfighters' perspective, removed systems would become available 35 days and 10 days sooner, for the AN/TPS-75 and AN/TRC-170, respectively. These calculations were based on data collected during the first six months of the pilot.

Tobyhanna is currently extending the RFID system to cover overhaul and repair of the Firefinder system (AN/TPQ-36 and AN/TPQ-37) and expects further expansions in the future.

Life Raft Project

Conducted as one of the ATOS ACTD series of demonstrations, the Navy's Life Raft Project used the ATOS active tag. Life rafts are subject to multiple recalls, as well as a mandatory inventory requirement, and cross decking between ships. Accordingly, the goals were to support near real-time inventory of high-value assets, allow personnel to conduct inventories at a safe stand-off distance, and maintain life raft environmental histories. Active tags were placed in cloth pockets that were attached to the inside of life raft clamshells. The tags held data on a life raft's manufacture date, recertification date, and flare serial number, as well as life raft identification.

The demonstration included operations aboard a ship to assess the ability of the RFID reader to detect tags in the presence of potential interference from: (1) steel structures that can result in multi-path propagation and signal nulls, and (2) shipboard electronics. At Norfolk Naval Shipyard Life Raft Repair Facility tags were attached to 43 life rafts from the USS Wasp that were being recertified. The life rafts were subsequently returned to the USS Wasp and placed in their stowage locations. All tags could be read from the flight deck aboard the ship, although bottom row life rafts required several read passes. All port side tags could be read from the pier. Since most of a ship's electronics and radars are not powered up while in port, an underway test is still recommended for sea temperature readings and radio frequency interference. A ROI analysis estimated an annual savings in excess of $133,000. This figure does not include any savings realized by improved asset control, such as an additional cost avoidance of $8,000 per raft from avoiding the purchase of unnecessary replacement rafts.

4. DoD's Use of Passive RFID

Organizations ranging from repair depots to one of the Navy's Fleet Hospitals have undertaken passive RFID efforts. The driving impetus behind most such efforts has been the need to develop the skills and technical infrastructure required to meet DoD RFID Policy requirements.

The following discussions are based on fifteen efforts for which information was available from the participating organizations. Of these, three were completed within the last twelve months, and another two are expected to finish by the end of 2006.

Characterization of Passive Efforts

DoD's passive RFID efforts share two overarching and related goals. The first is to increase the visibility of goods in the supply chain. The second is to increase data accuracy and process efficiency by automating the collection of data needed to update logistics AISs. Most efforts have additional goals specific to their organizations' assigned responsibilities. One of the objectives of the Ocean Terminal ePC Project, for example, was to increase inventory accuracy in cross-docking operations, and the Advanced Traceable and Control (ATAC) Passive RFID Integration for Retrograde Management pilot sought to reduce inventory losses that pose a challenge for retrograde shipments.

Types of Application

All of the efforts support shipping and receiving activities to some extent, though few use passive tags for all related activities, such as recording the arrival of shipments, reconciling contents against manifests, directing storage of supplies, guiding picks and freight consolidation, and generating shipping transactions. More than half of the efforts cover additional activities:

- Inventory management,
- Warehouse management, or
- Shelf-life management.

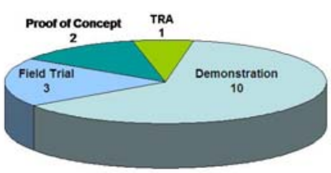
Inventory management efforts use passive tags to provide near real-time inventories. Some also use tag data to monitor the content of storage bins and support issuing supplies. As yet, there is no evidence of exploiting the information provided by the use of passive tagging for advanced functions like automated reordering of supplies as stocks diminish. Warehouse management applications use tag data for additional activities such as location detection and space management. A review of current industry uses of these applications is provided in a companion document [IDA 2006].

The single shelf-life management effort, the Combat Feeding Global Asset Visibility (GAV-RFID) technology demonstration, employed additional semi-passive tags with sensors to monitor environmental conditions and provide additional memory for tag data. DLA undertook this effort in collaboration with the Army. Used to the fullest, data on environment conditions can be used to predict product quality and, as necessary, guide sampling of supplies for inspection. This helps to ensure that supplies nearing the end of their useful life are issued first, and that only supplies still of high quality are used. In the GAV-RFID demonstration, a temperature sensor was used on pallets. When supplies reached their destination, temperature data from one pallet in each container was read and data used with a shelf-life model to derive a quality index.

In addition to examining the performance of passive RFID technology for inventory management processes, the Navy's Ready Service Spares (RSS)/Strategic Systems Program (SSP) Block Modules Inventory Management pilot conducted a series of technology tests. These focused on electromagnetic interference (EMI), environmental testing, functional testing, and the resistance of passive tags to physical damage. The performance of a number of different commercially available tags was tested (Encapsulated Stick, Free Space Insert, Intelligent ID Card, Reusable Plastic Container, Reusable Container Insert, and Container tags). Both the use of the technology for inventory management and the functional testing were performed in an Equipment Test Section of a Fire Control Station onboard a Trident submarine.

Types of Effort

Unlike the more mature active RFID technology, there are no passive RFID ACTDs. The efforts are variously reported as proof of concept studies, technology demonstrations or pilot studies; one has been labeled a Technology Readiness Assessment.



Three of the efforts were conducted as field trials, or initial capability implementations, in which RFID technology was applied in daily operations. These were the ATAC Passive RFID Integration pilot, the Ocean Terminal ePC Project, and the RFID Tag Military Shipping Label (RFMSL) pilot. Field trials involve some risk to daily operations that does not arise when the technology is investigated using stand-alone activities, but they provide greater assurance that results are meaningful. In particular, the results of these three efforts are based on processing large numbers of actual shipments and, presumably, included the types of special cases and other non-standard events that can occur in practice.

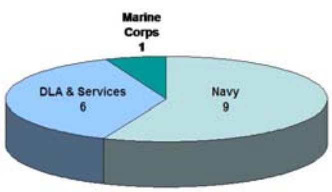
Most of the other efforts used some set of RFID-enabled business processes that were performed in parallel or otherwise separate from operational processes. These demonstrations often used a limited amount of supplies. In some cases only a small number of tagged supplies were available during the demonstration period. For example, only 10% of the supplies that arrived during the Value Chain Prototype demonstration were tagged (54 items). In some cases, technology constraints imposed the limitation. Only forty-seven of fifty tags available from the commercial supplier for use in the RSS/SSP Block Modules Inventory Management pilot, for example, were consistently readable. Another fairly common way in which this set of efforts differed from operational use was in how tag data were used in logistics AISs. More often than not, tag data were transmitted to a database or application specifically designed solely for the demonstration. This means that any follow-on implementation still has to address how tag data should be integrated into existing logistics AISs.

A Technology Readiness Assessment (TRA) is a formal process. In accordance with DoDI 5000.1, Operation of the Defense Acquisition System, it may be required in acquisitions prior to a Milestone B (System Development and

Demonstration) decision to determine whether the relevant technology is sufficiently mature to proceed with system development. The TRA conducted for the Fleet Hospital Support Office (FHSO) Expeditionary Medical Unit (EMU)-Delta Medical Automated Asset Tracking effort was performed by an independent validation and verification (IV&V) team, who followed the guidelines of MIL-STD 105E, Sampling Procedures and Tables for Inspection by Attributes. A variety of AIT technologies were examined: linear bar code, InfoDot (metal bar codes, metal labels, acrylaide), Metal InfoSite (metal bar codes), contact memory buttons (CMBs), and passive UHF RFID. (The practical utility of Iridium modem and satellite tracking was also investigated.)

Participants

DLA’s investigations into the use of passive RFID technology have been performed in collaboration with the Services. One effort was with the USAF, two with the Army, another with the Marine Corps, and an additional two were conducted with the Navy. All but one of the other efforts were conducted by the Navy working alone. This seems to imply that the Navy is taking the lead for the Services in looking into uses of passive RFID technology, but may only mean that information on any work being conducted by the USAF, Army, and Marine Corps is not publicly available.



Five of DLA’s six passive RFID efforts investigated the use of passive RFID technology for shipping and receiving. This focus on shipping and receiving has been necessary to ensure that DLA was ready to meet the timeline requirements of DoD’s RFID Policy. Another effort, performed in collaboration with the Navy, used passive RFID tags to support inventory management. Since DDC operations also necessitate warehouse management, it is likely that DLA can benefit from the knowledge and experience others are gaining in the use of passive RFID for those business processes. As DLA responsibilities extend to include management of repair depot supply operations, the Navy’s experience with retrograde shipments at the Norfolk ATAC and the Al Asad Remote Support facility also may become relevant.

Dates

The first DoD-funded investigation into the use of passive RFID, the Nuclear, Biological, and Chemical Defense (NBCD) Joint Service Lightweight Integrated Suit Technology (JSLIST) Pilot, examined the shipping of tagged supplies for four months in mid-2002. More than a year passed before the next effort. The majority of the efforts discussed here were performed in 2004. Fewer were conducted in 2005 and, at this time, only two demonstrations are planned for 2006. More details are given in Figure 2. This figure omits the Base Level Item Tracking System effort that is on hold pending clean-up activities after Hurricane Katrina.

Coverage of DoD Supply Chain

Supply Chain Nodes

There are examples of the use of passive RFID technology at each type of node in the DoD supply chain (supplier, DDC, Service Depot, Repair Depot, Base, Port of Embarkation (POE), Port of Debarkation (POD), TDC, warfighter). The term Base is used broadly to include, for example, Navy ships. The scope of each

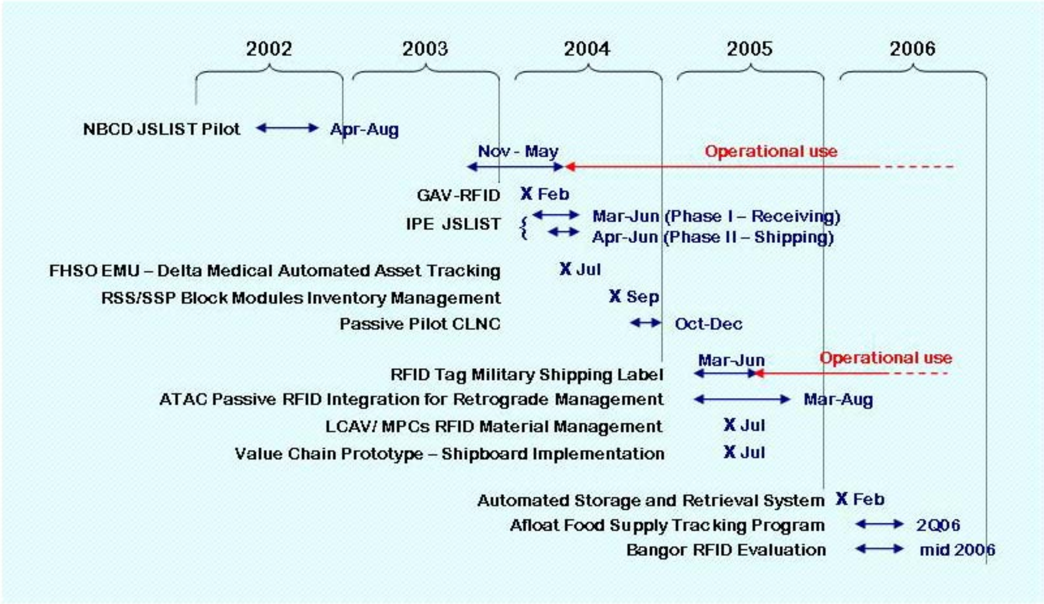


Figure 2. Timing of Field Trials and Demonstrations

effort, in terms of the supply nodes covered in demonstrations and field trials, is illustrated in Figure 3.

Most of the efforts involved sustainment supplies. The exceptions were the FHSO EMU–Delta Medical Automated Asset Tracking effort that included build-up processes that occur preparatory to a unit move, and the ATAC Passive RFID Integration pilot that affixed passive tags to retrograde shipments.

Examples of Tagged Supplies

- Depot Level Repairables
- JSLIST assets
- Meals, Ready to Eat
- SWS Block Modules

As noted in Figure 3, two efforts simulated supply chain nodes. One of these, the GAV-RFID demonstration, was conducted in a warehouse at DDJC. Stations to provide the functionality of ten points in the supply chain were set up using indoor and outdoor areas, representing materiel moving from a DoD supplier to an Army unit in the field. This approach has the advantage of providing an overall view of proposed operations, in a timely and cost-efficient manner. It is particularly strong in helping to assess the ability to, and effect of, sharing of data among nodes and in identifying how activities at one node can impact activities at other nodes. The main disadvantage is that problems arising from practical considerations, such as the placement of read portals and variations in traffic flow, may not be identified. The other effort that simulated supply chain nodes was the Navy's FHSO EMU-Delta Medical Automated Asset Tracking effort. In this case, the focus was on comparing the performance of different types of AIT tagging on the processes involved in preparing EMU-Delta for shipping. Again, the evaluation took place in a warehouse, this time located in the Naval Weapons Station Yorktown. The RSS/SSP Block Modules Inventory Management pilot also conducted a simulation of the relevant business processes, but this is not shown on Figure 3 because the simulation was a prelude to an *in situ* demonstration.

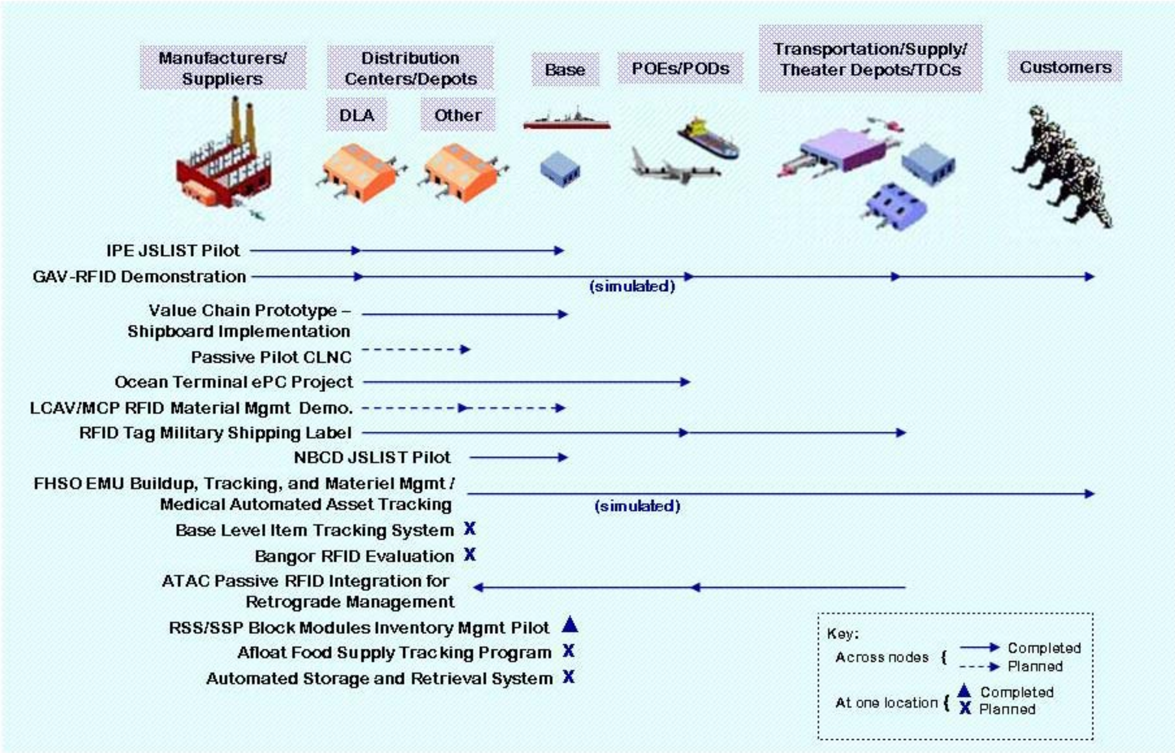


Figure 3. Passive RFID Coverage of Supply Chain Nodes

Other than the GAV-RFID demonstration, the only effort that examined using passive RFID tags to achieve the exchange of information between a DoD supplier and node in the DoD supply chain was the IPE JSLIST pilot. At the other end of the supply chain, the GAV-RFID demonstration and FHSO EMU-Delta Medical Automated Asset Tracking effort were the only ones that examined (simulated) final delivery of supplies to the warfighter.

Tagged supplies from DDJC and DDSP have been used in several efforts. In addition to passing supplies between them, shipments from these DDCs have been received at the Material Processing Center (MPC) Norfolk, the Fleet and Industrial Supply Center (FISC) Norfolk, Bluegrass Army Depot, and Camp Lejeune. At all but the last site, passive tag data were used to reconcile received supplies against shipping notices. Scanning of passive tags was used either as a Transaction of Record for shipment receipt or to supplement other record keeping. In the Value Chain Prototype and Logistics Center Customer Asset Visibility (LCAV)/MPC RFID Material Management demonstrations, tagged supplies from DDSP that arrived at MPC Norfolk were then assembled and forwarded onto the USS Nassau. Here, again, passive tags were read as part of the receiving process.

Passive tags were used on OCONUS sustainment shipments in the RFMSL pilot. This effort involved the largest number of supply chain nodes. Tagged shipments originated at three CONUS Air Force Bases (AFB) (Charleston, Dover, Seymour-Johnson) and DLA's AIT Logistics Center at Tinker AFB. They were received at Dover Aerial Port and consolidated into airfreight. The supplies were then airlifted to Ramstein AFB for final delivery to Ramstein and Spangdahlem TDCs. In the ATAC Passive RFID Integration for Retrograde Management pilot, passive RFID technology was used to track parts shipped from ATAC Norfolk to DDNV, and from the OCONUS ATAC Mobile Node at Al Asad AFB in Iraq to ATAC Norfolk.

Depot Processes

The two efforts that have made the widest use of passive tag data with respect to business processes are the GAV-RFID demonstration and the Ocean Terminal ePC pilot. Between them, these two efforts cover most of the different business processes examined in the full set of passive RFID efforts. The exception is the use of readers associated with storage bins that can capture current 'shelf' status. This capability was examined in RFMSL pilot.

Figure 4 illustrates the operation of the simulated General Supply Point in the GAV-RFID demonstration (operations at a Depot and a Direct Support Supply Point were also included in the demonstration). In addition to the use of environment data for calculating a quality index and corresponding treatment of shipments, this demonstration is notable for using passive tag data to automatically increment and decrement a bulk storage inventory and an issue area inventory and for generating pick lists that allowed an RFID-enabled forklift operator to locate needed supplies.

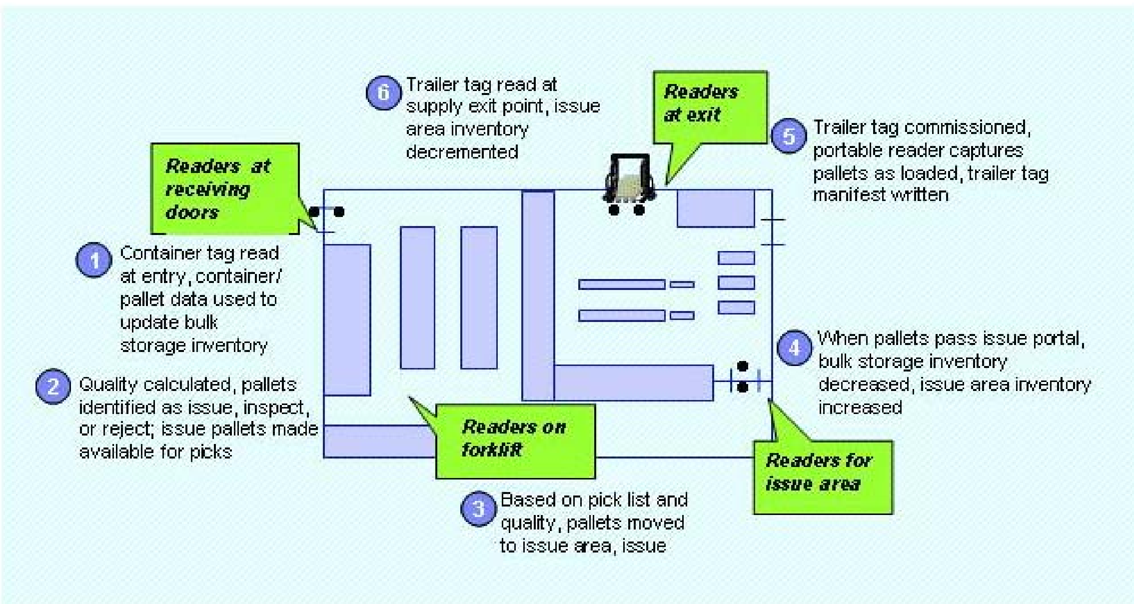


Figure 4. GAV-RFID General Supply Point Process Flow

The use of passive tags is fully integrated into operations at the FISC Norfolk Ocean Terminal Container Freight Station (CFS). A special RFID reader tunnel was developed that uses more than one reader to allow reading tags on variously sized and shaped packages on a pallet, while eliminating the majority of extraneous reads from the surrounding area. Two of these tunnels are used, with a single operator located between them. As shipments arrive, data from the passive tags are used to record shipment receipt. The identification also allows the Ocean Terminal Management System (OTMS) to print a FISC local handling label. This, in turn, allows shipments to be stowed by destination until the appropriate container is ready for loading.

As shipments are taken to be loaded, they pass through a reader portal that is preset for each pallet so that it will be possible to ensure that all the passive tags are read (if necessary, missed tags can be scanned by a bar code reader). These reads are used to update the OTMS transaction record. When loading is complete, an active tag is created that contains the container manifest. These processes are illustrated in Figure 5.

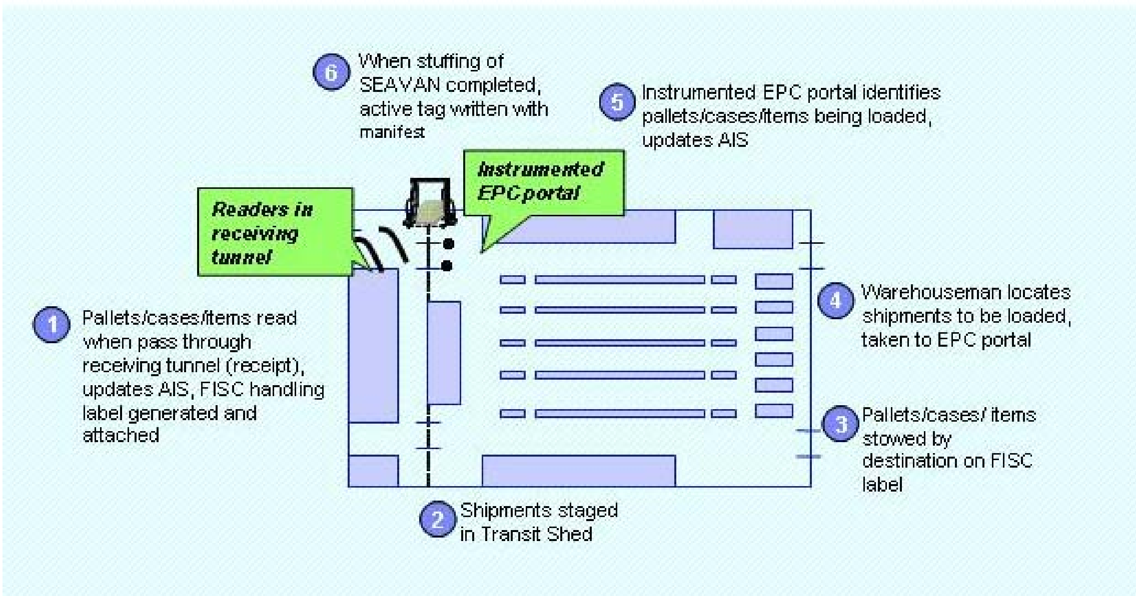
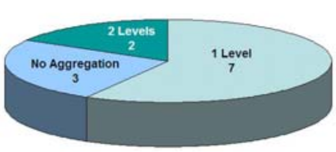


Figure 5. Ocean Terminal ePC Process Flow

Use of Passive Tags



Among the field trials and demonstrations that have been completed, most used passive tags on cases of supplies or on large items. The RSS/SSP Block Modules Inventory Management pilot, handling high-value assets, affixed tags to individual Strategic Weapon System Block Modules, even though these are relatively small circuit boards. The NBCD JSLIST pilot attached tags only to pallets of assets. In all these cases, the tag data provided a link to details maintained in a logistics AIS, such as product ID and Supplier Name. Seven efforts used an additional passive tag on pallets (or next level of supply grouping). Here, the pallet tag data provided a link to the association of cases to pallets that were maintained, along with other shipment details, in an AIS.

With its use of semi-passive tags, the GAV-RFID demonstration was a special case. Passive tags were attached to cases of Meals, Ready to Eat (MREs) and Unitized Group Rations (UGRs). Once the cases were assembled on a pallet, each pallet was shrink-wrapped and an additional passive tag attached to be used as a check tag for the pallet's integrity. A semi-passive tag with additional storage capacity and a temperature sensor was also attached to each pallet to allow data aggregating cases to pallets and data on environmental conditions to be stored the tag. As pallets were loaded into containers for shipment, an additional semi-passive tag was used to provide a second level of aggregation:

pallets to containers. The container tag provided access to sufficient information to generate a Transportation Control and Movement Document record.

Based on reported information (ten of the fifteen efforts), EPC Class 1 passive tags were the most commonly used. The RFMSL pilot used both Class 0 and Class 1 tags, and the Passive Pilot CLNC used EPC Class 0 tags. The RSS/SSP Block Modules Inventory Management effort was the only one that used EPC Class 2 tags.

RFID and Bar Codes Twelve of the fifteen passive RFID efforts are known to have previously relied on bar codes for case and large item supply management and this is also likely to be true for the other efforts. In the passive RFID efforts, the use of bar codes continued. The role of the bar codes changed, however, with bar codes used as a back up AIT for those instances where a passive tag was missing or unable to be read. How long bar codes will continue to be needed in this way depends on the rate of improvements in the reliability of passive tags and tagging processes. Meanwhile, the use of two forms of AIT does incur additional cost to DoD's suppliers. It also requires DoD supply nodes to be able to read both forms of data.

Findings Related to Business Processes

As might be expected from the range of applications where passive RFID tags have been used, in some cases the technology met, or even exceeded expectations, while in others it was found unsuitable for use at the current time. The following discussion groups together those efforts where operational use has been recommended, even if the sponsoring organization is still waiting for funds to proceed.

This discussion includes only eleven efforts, since the others are still in progress or, in the case of the LCAV/MPC RFID Material Management effort, the final report has yet to be released.

Operational Use The FISC, Norfolk, Ocean Terminal CFS ePC pilot began in November 2003. Initially, passive EPC Class 1 tags were affixed only to shipments arriving via small package carrier. After an initial Quality Control Initiative, the success of tag read tests quickly led to a larger pilot effort. Starting in January 2004, the CFS began using passive RFID for the receipt of all shipments except household goods, classified shipments, and outsized or overweight shipments, all of which require special processing in different parts of the facility. A later expansion of the pilot led to the full implementation of RFID technology for the Ocean Terminal stuffing process. The system has been in operational use since May 2004, covering activities from the arrival of cargo by truck, through staging, to loading into SEAVAN shipping containers. The reliability of RFID data during this process is considered high enough that it is used for Transactions of Record. In addition to meeting the original goals of increasing manifest accuracy and inventory accountability, RFID technology is credited with increasing the efficiency of the cargo checking process [FISC 2004].

The GAV-RFID demonstration was also one of the early DoD investigations into passive RFID, with the first contract awarded in February 2003. This demonstration included many 'firsts,' including two levels of aggregation (case to pallet, and pallet to container), development of an RFID-enabled wireless forklift system, and use of temperature sensor augmented semi-passive tags. In addition to using passive tags on cases for identification purposes, an additional passive tag was placed on pallets as a 'check tag' whose presence could be used to indicate pallet integrity. There are no published data on process performance metrics or tag read rates, but extensive sets of lessons-learned provide insight into the technology used [Oat 2004]. This was another successful demonstration and the participating organizations are ready for the operational use of passive RFID. Investigation into the use of temperature sensors on semi-passive tags continues. In summer 2005, temperatures were recorded in two storage facilities in Iraq and Kuwait to gather data that could be used to identify where this capability is most needed. Infrastructure needs are still being determined, as well as other places in the supply chain where the capability could be useful. Other work at the Natick Soldier Center Combat Feeding Program is researching how passive tags can be integrated into pallet wraps to provide pallet-level security.

The Navy's ATAC transportation system manages the movement of retrograde materiel. In addition to verifying the utility of passive RFID technology in a high-volume environment, the ATAC Passive RFID Integration for Retrograde Management pilot was conducted as a field trial to investigate the potential to improve processes and enhance asset visibility, as well as assess passive RFID implementation costs. From March to August 2005, repairables arriving at ATAC Norfolk from various overseas facilities were tagged and shipped to DLA's Defense Depot Norfolk, VA (DDNV), where the tags were used to confirm receipt. From July to August 2005, the ATAC facility in Al Asad also began affixing passive tags to repairables they shipped. In addition to verifying the utility of passive RFID technology in a high-volume environment, this pilot successfully demonstrated how the use of passive tagging could enhance the visibility of retrograde assets. Naval Supply Systems Command (NAVSUP) hopes to receive funding to start operational use, including integrating the RFID capability into the electronic Retrograde Management System (eRMS). For the next steps, NAVSUP is looking to execute a planned Okinawa-San Diego prototype, establish an RFID data repository and implement the system at remaining ATAC sites. NAVSUP also plans to use RFID to facilitate its interaction with commercial repair and transportation organizations.

The USAF RFMSL initial capability pilot is the effort that included the most nodes in the supply chain, using RFMSLs with embedded passive tags on U.S. Central Command (CENTCOM) sustainment pallets. One of the main goals was to improve efficiencies in in-transit processes by reducing the amount of labor involved with collecting data and associating cases with pallets and pallets with containers. Demonstrating consistent data transfer among supply chain partners was equally important. Goals were met, although tag read rates are not sufficiently reliable to allow tag data to replace current ITV Transactions of Record, only to supplement them. The next step is to work with USTRANSCOM and Headquarters, USAF Air Mobility Command (AMC), to instrument two additional aerial ports. The AMC is funded for this work. There are also plans for the integration of passive tag data into the Logistics Data Warehouse AIS.

Further Development

The Value Chain Prototype demonstration used passive RFID for receipt, stow, and issue processes onboard Naval ships, embodying the Navy's Smart Stores concept and the Integrated Visibility Manager. The project was also an extension of the LCAV/MPC RFID Materiel Management effort. The goals of the demonstration were met, in that Receipt in Process transactions occurred in real-time, and the RFID-enabled processes offered both the desired mobility and flexibility while minimizing operator input and reducing specialized skill requirements [NAVSEA 2005]. However, additional work was recommended prior to operational use to investigate changes to business processes and enhanced AIS connectivity. Additionally, technology issues such as the effect of packaging and environment conditions on tag readability and the disassociation of packages and tags must be resolved, and the ability to 'kill' tags improved.

No Further Action

The Passive Pilot CNLC was conducted in October 2004. Sustainment parts were tagged at DDSP and shipped to the 2nd Supply Battalion, Camp Lejeune. This was essentially a technology test designed to establish whether tags on received supplies could be read. The results were mixed, though no detailed analysis has been reported. There have been no follow-on activities.

The pilot that used passive RFID to provide visibility into the supply, issue, and retrieval of NBCD JSLIST suits was conducted to respond to GAO concerns about the visibility and shelf-life management of NBCD assets. It began in April 2001 and ran for several months. In addition to tracking the movement of NBCD JSLIST asset across supply chain nodes, it captured information about the issue and retrieval of items from individual Marines, including condition on return. The demonstration was successful, and followed by approval by key agencies to expand the scope into a larger NBCD joint assets visibility effort. There was no further use of this RFID capability, although a similar capability is now being considered for tracking assets going into consolidated storage facilities.

Technology Immature

Technology Readiness Levels

1-Idea
2-Technology concept
3-Analysis
4-Lab
5-Breadboard
6-Prototype, simulated
7-Prototype, operation
8-Qualified system
9-Proven experience

The TRA of passive RFID technology, performed for the FHSO EMU-Delta Medical Automated Asset Tracking effort, was the only one of these efforts that contrasted the strengths and weaknesses of alternative AITs for a set of business processes. Quantitative performance assessments of the AIT technologies considered reliability, accuracy of data, and, for bar codes, print quality. Additionally, the use of each technology in a set of EMU-Delta build processes was analyzed to determine its sufficiency. In a TRA, technologies are rated on a scale from 1 to 9, with 9 being the highest level of Technology Readiness. The various bar code devices were rated at an 8 (Qualified System) or 9 (Proven Experience) level, CMBs were rated as 9, but passive RFID rated only a level of 6 (Prototype Operation). The IV&V assessors concluded that passive RFID technology could eventually be used with certain types of FHSO packing cases, but that the unreliable reads that resulted from the close proximity of packing units in assembly operations, and the high metal content of packing cases, made the technology unsuitable for immediate use. This evaluation was conducted in mid 2004, and some of the reported deficiencies with signal isolation and distinguishing multiple reads have been reduced in newer products.

The RSS/SSP Block Modules Inventory Management pilot was also carried out in mid 2004. This work demonstrated that passive RFID technology was capable of performing the functions intended. However, the empirical results of the EMI testing indicated that the portable RFID reader used failed by a narrow margin to meet MIL-STD 461, DoD Interface Standard Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment Requirements for Submarines, and lacked technical maturity and market development. Although passive tags provided high data integrity, the tag detection rates were too low (50% to 90%) and performance was too variable. Also, the stand-off counting methods (that is, with no visual contact) that RFID technology affords are not regarded as sufficiently reliable for high-value assets. The project reached the conclusion that passive RFID technology was not suitable for the inventory of SWS Block Modules onboard Trident submarines at that time due to environmental concerns and the existing information infrastructure, as well as a lack of technology maturity.

The IPE JSLIST implementation, conducted in early to mid 2004, examined the use of passive tags to address problems with receipt and asset visibility. The major goals were to demonstrate the integration of RFID data into a legacy AIS and support shipping and receiving processes. Passive RFID technology was found to lack maturity, with problems in both hardware and software. For example, read rates during receipt processes varied from 16.17% to 45.45% for cases and 40.83% to 50% for pallets (read rates were higher during shipping processes, but still highly variable and with a maximum of only 73.3%). Also, approximately 20% of the Class 1 tags initially received from the vendor were bad. Use of RFID in this context also adversely affected processes, requiring slightly longer times to process each pallet.

Findings Related to Benefits

Only three of the passive RFID efforts have reported specific benefits that were attributed to the use of the technology.

The Ocean Terminal ePC project was intended to prepare the CFS to meet the requirements of the DoD RFID Policy, and increase manifest accuracy and inventory accountability. It was not designed with the goal of providing a financial ROI. As of October, 2004 [NAVSUP 2004], no financial ROI had been realized, but there had been a sufficient improvement in operational efficiency to allow a reallocation of manpower within the organization. Depending on the number of SEAVANS being loaded, as many as twelve personnel became available for other work. A test was conducted that compared the legacy manual documentation process for stuffing a SEAVAN with the RFID-enabled process. Using a small sample of containers, the average stuffing times were reduced by 33%, and for an actual item count of 54, the average items counted were 52.4 (legacy) and 53.9 (RFID). Additionally, the average number of shipments flagged as potentially lost dropped from 4.0% before the pilot began to 1.8% in the second half of FY04.

During the ATAC Passive RFID Integration for Retrograde Management field trial, a total of 12,542 shipments were tagged at ATAC Norfolk and Al Asad, with a total value of over $200M. Automated receipt information from RFID tags at DDNV identified 355 shipments, accounting for $12.6M, where no Proof of Delivery (POD) was recorded in eRMS. The identification of these shipments eliminated the need for ATAC personnel to do further research and prevented a potential loss of the material. Also, the RFID tags confirmed delivery of more shipments than bar codes (bar codes only confirmed 97.1% of items as delivered).

The Value Chain Prototype-Shipboard Implementation project examined three test scenarios: (1) processes with existing AIS support, (2) processes supported by a modified AIS, and (3) processes supported by the modified AIS and passive tagging [NAVSEA 2005]; an approach that allowed identifying the impacts of just passive RFID technology. The findings were that passive RFID provided superior response times to current bar code practices, primarily because multiple items (tags) could be processed at the same time. The maximum extent of advantage depended on the materiel movement process, not the technology capability alone.

Findings Related to Read Rates

Read rates are one performance measure used for passive tags. In some ways, the term 'read rate' is a misnomer. The problem is one of detecting tags; once a tag has been detected there is rarely a problem acquiring accurate tag data. Low read rates are often cited as a primary reason why passive RFID technology is unsuitable for practical use at the current time, but it is important to understand that not all of the causes for reported low read rates are technological. The efforts discussed here provided many examples of occasions where process or actions adversely impacted read rates. Examples include when supplies were brought into a depot through a portal that was not instrumented or missed a printing station, when pieces of equipment were not being switched on or power failed, and problems with the wireless network and logistics AIS that prevented recording read events.

> "I had a tag that showed up for about 40 days [as being read], coming in and out of a grocery store's stock room. I knew something was wrong. Turns out someone was reusing the tagged box for bringing stock out to the floor. "
> *Kevin Brown, Director of Information System, Daisy Brand*

Whatever the cause, it is clear that some form of validation is necessary to improve read rates. At least two efforts, the LCAV/MPC RFID Material Management demonstration and the Passive Pilot CLNC pilot, read tags at multiple locations under different conditions to provide more complete detection of tags. Using this approach, read rates of 98.1% and 96% were reported, respectively. It is uncertain whether this approach would prove feasible in an operational environment. A more practical alternative was demonstrated in the Ocean Terminal ePC pilot. Here a read portal was linked to the logistics AIS so case and pallet aggregation data could be used to determine whether all expected tags had been read and appropriate instructions provided to the operator and/or forklift driver. The ATAC Passive RFID Integration for Retrograde Management pilot found that using an instrumented portal and case and pallet aggregation data increased supply visibility to 99.6%, compared to 63% for unattended reads.

Tests of the new EPC Class 1 Gen 2 tag show higher read rates than those exhibited by the first generation of commercial UHF tags. However, as indicated above, operational read rates may still be reduced by inappropriate process and personnel actions.

Findings Related to Harsh Environments

Since many of the supplies distributed by DLA are transported, stored or delivered in harsh environments, the performance of passive tags under such conditions is a concern.

Ship and Submarine

The heavy metal infrastructure and large number of reflective surfaces of ships present a difficult electromagnetic environment for the operation of RFID equipment. The typically close confines can also result in the proximity of numerous electronic systems such as radar, navigation, and power systems. RFID devices must not only operate in such environments but not interfere with other systems. The LCAV/MPC RFID Material Management demonstration and the Value Chain Prototype-Shipboard Implementation demonstration both are examples of successful uses of the technology aboard ships.

Submarines pose similar problems. Unlike surface ships, where radio frequency propagation tends to 'leak' through the hull into the surrounding air, submarines aggregate the effects of all the wireless devices on board. Thus, while the same types of emission requirements are imposed on both types of vessel, those for electrical field emissions are more restrictive for submarines. The EMI testing conducted as part of the RSS/SSP Block Modules Inventory Management pilot found that the emissions of the portable RFID reader used did not meet military standards.

Temperature and Humidity The environmental testing conducted as part of the RSS/SSP Block Modules Inventory Management pilot examined the performance of passive tags after exposure to high temperatures and 90% humidity. The manufacturer's recommended maximum temperature for the Encapsulated Stick tag was 122°F, so that tag was only exposed to 120°F, while the others were exposed to 170°F. All tags were left in a test chamber for a period of ninety-six hours. Once removed from the chamber, all tags were read successfully, even though some showed slight visible signs of damage.

Results from the Afloat Food Supply Tracking Program are not yet available, but are expected to provide data on the performance of tags and readers in shipboard storerooms where temperatures range from 0° to 80°F and conditions include high humidity and possible EMI from equipment such as freezer compressors.

Metal Containers Some DoD supplies are packaged in metallic materials or contain fluids. Since metal surfaces reflect and fluids absorb electromagnetic energy, this can make tag detection more difficult. The GAV-RFID pilot encountered reduced read reliability due to the metal content of MRE and UGR packaging and the high moisture content of case packaging. The problem was resolved by using double-sided tape to provide some separation between the tag and packaging, but this approach could add to costs and make a tag more susceptible to damage. The metal content still prevented reading tags in the middle of a pallet.

Strategic Weapon Block Modules, the supplies used in the RSS/SSP Block Modules Inventory Management pilot, not only have a high metal content but are often sealed in metal bags and stored in drawers in a metal cabinet. When items, packaged in an assortment of bubble wrap, plastic, anti-static material, and Mylar, were placed on a wooden table, a single scan detected the passive tags only 46.8% of the time. Achieving read rates of over 90% required the scanner to be repeatedly passed over an individual item (less than one foot away) for more than a minute. When the items were stored in the cabinet, read rates ranged from 70.2% to 83%, depending on the presence of foam packaging materials in the (open) drawer. This problem with metal and liquid supplies and packaging is an inherent constraint of the technology used in current passive tags. Chipless tags based on nanotechnologies and printed electronics are expected to provide better performance in such situations.

Damage RSS/SSP Block Modules Inventory Management pilot tested the effect of damage on a sample set of seven EPC Class 2 tags. These tags were physically stressed to simulate the effect of tag exposure to a harsh warehouse environment. They were subjected to folding, soaking in hot liquid, cutting in half with scissors, repeatedly being stepped on, being written on with a sharp pen, or crumpling. All seven tags were then read successfully three out of three times, even when a test operator held the two pieces of the cut tag apart, and when the previously-immersed tag still had a layer of liquid on top.

Current DDC Passive RFID Capabilities

After the final DoD RFID Policy was issued on 30 July 2004, DLA issued an Invitation to Volunteer for DoD suppliers to send tagged shipments prior to the Policy's January 2005 requirement. This announcement invited suppliers to participate on a strictly voluntary basis, with no contractual obligation or compliance enforcement requirements. GE Aircraft Engines and Lockheed Martin responded to this invitation, becoming the first DoD suppliers to deliver goods with passive tags. Since that time, DDCs have been receiving tagged supplies from additional vendors. Overall, such supplies currently form only a small proportion of those DLA handles. This volume is expected to grow in a manageable manner in response to the Policy's phased implementation approach and as DoD issues new supply contracts and renegotiates current contracts.

The infrastructure to process passive-tagged supplies will shortly be completed at DDJC and DDSP. These DDCs also have a limited ability to use passive tags in shipping processes. DLA expects read/write capabilities to be fully installed at all its CONUS DDCs by FY07. At the current time, tag data is only used for the date of receipt. DLA plans to start using the data for additional business processes later in 2006.

Initial use of passive tags has brought attention to the effects that disposing of passive tags might have on the environment. The National Council for Air and Stream Improvement (NCASI) conducted a research study in 2005 [NCASI 2005] to examine the environmental implications of recycling corrugated container packaging containing passive RFID tags. A preliminary study indicated that the plastic laminated copper foil antennae currently used in passive tags maintain their integrity during hydrapulping and are removed during initial screening and cleaning. These were not considered any further. Silver from the conductive silver ink used in antennae was tracked as RFID-bearing corrugated container clippings were processed through a pilot-scale recycling plant. Silver concentrations were measured in four output vectors: screening and cleaning rejects, whitewater settled solids, whitewater effluent, and product in runs conducted with and without RFIDs. These initial results indicated that no applicable regulatory limits would be exceeded.

Other questions related to how advances in technology might help to streamline the receiving and shipping of supplies. For example, the use of passive tags with a repeat write capability would allow DDCs to augment initial data provided on tags by suppliers, instead of printing new tags. Similarly, the use of packing cases and pallets with embedded passive tags may have helped to increase the efficiency of some processes and eliminate some of the personnel-related causes of poor read rates.

5. Integration of Passive and Active RFID

Using active and passive tags for full associations from cases, to warehouse pallets, to shipping containers or airfreight 463L pallets offers several benefits. For example, as a container is loaded, feedback could be provided on what supplies remain to be added, and the loading of incorrect supplies could be detected. During transit, if necessary, container contents could be checked against those identified on the active tag without having to access a logistics AIS. Subsequently, the container manifest on the active tag could be updated automatically as supplies are removed, increasing the real-time visibility of supplies.

Previous Work

As described in the previous section, the GAV-RFID demonstration held in February 2004 used multiple levels of aggregation: cases to pallets, pallets to shipping containers, and pallets to vehicles as supplies moved from the simulated General Support supply point to the simulated Direct Support supply point. Although this effort used semi-passive tags instead of active tags, the same concepts applied. The semi-passive tags used in the GAV-RFID had sufficient data storage that pallet, container, and vehicle tags could each store a manifest of the loaded supplies. The results with respect to this use of tags were positive and illustrate the potential value of integrating the use of active and passive tags. Although it has no impact on active-passive RFID integration, it is worth noting that the Natick Soldier Center Combat Feeding Directorate found the smaller range of the semi-passive tags (compared to active tags) did pose a problem and they will continue to use active tags for containers. As previously mentioned, current work is assessing the infrastructure needed for operational use of the semi-passive tags, as well as looking at additional uses in the supply chain.

Ongoing Work

The major effort investigating the integrated use of active and passive RFID technology is the Alaska RAPID Project. This is a joint effort where DLA is working with USTRANSCOM, PACOM, USAF, and the Army. There is also collaboration with OSD, PM J-AIT, and DoD LOG-AIT. The project has two main parts: (1) the RFID Active Passive Intermodal Project (RAPID), and (2) training. The training part of the effort covers affected supply chain organizations from upstream (suppliers), through distribution personnel, to downstream (the warfighter). In the first phase of its spiral development, the RAPID project will use active and passive tags on shipments that originate at DDJC and Travis AFB, pass through the Port of Tacoma or the Port of Anchorage, and arrive at end users at Elmendorf AFB and Fort Richardson. There will also be partnership with two commercial carriers (Horizon and Alien). The second phase of development will extend the system to additional Alaskan military sites and include additional commercial carriers. It will also be used to support an Alaskan Joint Exercise and unit moves. In addition to increasing supply visibility, the project objectives include reducing the number of points where manual data entry is required, collecting metrics to validate business processes, and preparing a BCA and economic analysis. No results are likely before FY07.

6. Standards

The use of RFID is supported by an evolving set of standards. These address everything from data protocols to device compliance testing. Existing standards related to concerns about exposure to radio frequency, although longstanding, are also relevant. First, it is useful to understand the different bodies that are developing the standards.

Standards Organizations

Official standards (sanctioned by an accredited standards body) are developed by international, national, regional, and industry organizations.

International Bodies

RFID is covered by two major international standards bodies: International Organization for Standards (ISO) and the International Electrotechnical Commission (IEC). ISO and IEC have established a Joint Technical Committee (JTC1) to address technology standards. Standards that are developed by JTC1 are published as joint ISO/IEC standards.

The ISO/IEC JTC1 subcommittee most concerned with RFID technology is SubCommittee (SC) 31, Automatic Identification and Data Capture Techniques. This subcommittee deals with standardization of data formats, data syntax, data structures, data encoding, technologies for the process of automatic identification and data capture, and associated devices utilized in inter-industry applications and international business interchanges.

RFID ISO/IEC JTC 1 Subcommittees and Working Groups

ISO/IEC JTC1/SC31/WG 1-Data Carrier
ISO/IEC JTC1/SC31/WG 2-Data Structure
ISO/IEC JTC1/SC31/WG 3-Conformance
ISO/IEC JTC1/SC31/WG 4-Automatic Identification and Data Capture Techniques, RFID for item management
ISO/IEC JTC1/SC31/WG 5-Real Time Locating Systems

Other International Committees

ISO TC 104/SC4/WG 2-Automatic Electronic Identification for containers and container related applications
ISO TC 122/Ad Hoc Group Packaging Bar code Labels
ISO TC 204 RFID for Transportation and Control Systems

National Bodies

The American National Standards Institute (ANSI) does not itself develop American National Standards (ANSs). Instead, it provides interested U.S. parties with a neutral venue in which to come together and work towards common agreements. ANSI is the sole U.S. representative and dues-paying member of the ISO and, via the U.S. National Committee, the IEC.

Groups working to create ANSs for RFID include:

1. The Material Handling Industry (MHI), Accredited Standards Committee (ASC) MH10 that provides standards for transport packages and unit

loads. It represents U.S. interests within the scope of the relevant ISO work.

2. The InterNational Committee for Information Technology Standards (INCITS) T6, Radio Frequency Identification, was established to develop non-contact interface protocol standards for electronic transponders and interrogators for business and military logistics applications. INCITS T20, Real Time Locating Systems (RTLS), addresses the weaknesses of conventional supply-chain management systems with wireless technology by providing instantaneous location, tracking, and management of supply-chain resources.
3. The Consumer Electronics Association (CEA) develops standards relating to consumer electronics products and related services, and transmission signals that may traverse the demarcation points of telecommunications infrastructures.

Regional Bodies

There are two main regional standards organizations in Europe that deal with RFID standards. They are the European Telecommunications Standards Institute (ETSI) and CEN, the European Committee for Standardization. ETSI is responsible for standardization of Information and Communication Technologies (ICT) within Europe. The EMC and Radio Spectrum Matters Committee (TC-ERM) is the formal interface with respect to radio spectrum and electromagnetic compatibility between ETSI and international and European standards groups. CEN focuses on voluntary technical standards that promote free trade, the safety of workers and consumers, interoperability of networks, environmental protection, exploitation of research and development programs, and public procurement.

Trade conflicts between the European Union (EU) Commission and the U.S. are preventing stabilization with regard to the syntax and the semantics of basic RFID signals. This can be seen in the differences embodied in the ANSI and ETSI work.

Industry Bodies

Benefits of Accreditation

Ensures:
- Standards are:
  - Relevant
  - Responsive
  - Performance-based
- Process is:
  - Consensus-based
  - Open & transparent
  - Due process
  - Flexible & timely

Technical standards can also be developed by broadly based organizations such as the Association for Automatic Identification and Mobility (AIM) and EPCglobal. In this context, the term “standards” does not necessarily imply ratification by a recognized accreditation body, since the organizations are not accredited standards committees. Some industry standards are put before such bodies as, for example, has happened with the EPCglobal Gen 2 RFID specification that is expected to become an ISO standard in March or April 2006.

AIM Global is a global trade association comprising providers of components, networks, systems, and services that manage the collection and integration of data with information management systems. In 2004, a group of RFID expert advisors initially chartered by DoD became an expert advisory group within AIM Global. The group, known as the RFID Experts Group, has been working with DoD to address implementation issues related to supply chain adoption of RFID systems.

EPCglobal Inc™ is a not-for-profit organization entrusted by industry to establish and support the EPCglobal Network™ as the global standard for real-time, automatic identification of information in the supply chain of any company, anywhere in the world. It develops and administers EPC standards going forward. This work is supported by the MIT Auto-ID Laboratory that is one of a federation of six Auto-ID Laboratories around the world engaged with the EPCglobal standards organization in developing products, systems and standards.

Identification Standards

One of the principal applications of RFID in supply chain management is to support the change in inventory management systems from a basis of counting like objects having a common stock keeping unit, to total asset visibility systems where every item is uniquely identified. Unique identification is performed by the addition of a serial number to form a transponder data structure such as an SSCC-96 (Serialized Container Code) or an SGTIN-96 (Serialized Global Trade Item Number) that supports identifying unique items at the unit level as well as at the case and carton levels.

Identification standards deal with how unique item identifiers or other data on an RFID tag is coded. It is essential for the exchange of information among trading partners, in this case all the organizations that supply, store, and move items in the DoD supply chain. The importance of item identification standardization was stressed in a 15 January 2005 briefing by USTRANSCOM to the DoD AIT IPT [USTRANSCOM 2005b]:

> "The use of multiple, non-standard formats for SEAVAN ISO container numbers is causing loss of in transit visibility (ITV) and therefore asset visibility...In recent studies of RFID tagged containers, there is only a one percent container number correlation between the Global Transportation Network (GTN) and the RFID Regional In-transit Visibility (RITV) servers."

Existing Standards

There are long-established standards that are used to identify items uniquely, such as the traceability standards in ISO/IEC 15459. In development are additional standards to cover items and returnable containers. There are also standards for the data dictionaries of various data elements that have been used for many years for exchanges in bar code format. These individual data elements cover data, such as order number, delivery address and up to 100 other data elements that are relevant for item attendant data capture. Relevant standards are listed in Table 5.

DoD IUID Policy

On 29 July 2003, DoD issued a policy regarding the use of item unique identification (IUID) codes. This policy requires that qualifying DoD items be marked with a two-dimensional data matrix encoded with a Unique Item Identifier (UII). The UII is globally unique and permanent for the life of the item. The policy specifies that, starting 1 January 2004, all solicitations of tangible assets that meet certain requirements, such as an acquisition cost greater than $5,000, will include a requirement to use IUID's. The policy relies to the maximum extent practical on DoD recognized equivalent commercial item markings to avoid introducing government- unique data requirements. UII syntax must comply with ISO/IEC 15434 and the semantics must comply with ISO/IEC 15418.

DoD UID Requirement

- Contain an enterprise identifier
- Uniquely identify an individual item within an enterprise identifier, product or part number
- Have an existing DI or AI listed in ANSI MH10.8.2

In addition to identifying items being shipped, it can be necessary to uniquely identify active tags themselves. A new RFID standard (ISO/IEC 15963:2004) has been developed that allows either the chip or the RFID tag to be uniquely

DoD-Recognized Item UID Equivalents

Global Individual Asset Identifier
Global Returnable Asset Identifier
Vehicle Identification Number
Electronic Serial Number (cell phones only)

identified in a manner different from the encoded unique identifier of the item to which it is attached.

The latest version of the EPC Tag Data Standard conforms with DoD's UID policy and DoD's CAGE code and DODAAC, which are used by DoD suppliers to identify shipments. This now means that DoD's suppliers can use either these DoD tag data constructs or the EPC tag data construct to comply with the DFARS RFID rule. Prior to the new standard, an RFID reader needed special software to read CAGE, DODACC, and EPC formats.

Table 5. Status of RFID Identification Standards

		Existing	Pending
MIL-STD-129	DoD Standard Practice for Military Marking for Shipment & Storage	✓	
ISO 10374: 1991	Freight Containers-Automatic Identification	✓	
ISO/IEC 15418:1999	Information technology-EAN/UCC Application Identifiers and Fact Data Identifiers and Maintenance	✓	
ISO/IEC 15424:2000	Information technology-Automatic identification and data capture techniques-Data Carrier Identifiers (including Symbology Identifiers)	✓	
ISO/IEC 15963:2004	Information technology-Radio frequency identification for item management-Unique identification for RF tags	✓	
ISO 21007-2: 2005	Gas cylinders-Identification and marking using radio frequency identification technology Part 2: Numbering schemes for radio frequency identification	✓	
ISO/IEC 15434	Information technology—Automatic Identification and Data Capture Techniques—Syntax for High Capacity ADC Media		✓
ISO/IEC 15459	Information technology—Unique identification of transport units		✓
ISO 18185	Freight Containers-Radio-frequency communication protocol for electronic seal		✓
AIAG	RF returnable containers working group		✓
BSR MH10.8.9	Product Identification Using Technologies Other Than Optically Readable Media		✓
BSR MH10.8.10	RFID for Product Packaging		✓
EPCglobal	Tag Data Translation		✓

Ongoing Work

Current work on identification standards seeks to extend the types of data that can be encoded and the types of items that can be subjected to unique item identification. In addition, AIM Global is petitioning ISO to reserve 8 bits on the RFID tag protocols to carry Environmental Protection Agency recognized processes for recycling.

The finalization of one of the standards under development for freight containers, ISO 18185, is being delayed by a dispute between Motorola and other members of ISO Technical Committee 104, which has responsibility for shipping container standards. Motorola has raised a number of concerns about ISO 18185 including the absence of tag security, encryption, and interoperability. The revisions being pursued by Motorola could increase the cost of an e-seal between 50 and 200 percent. Carrier members of TC104 have been doing additional testing of elements of ISO 18185 since May, the results of which may lead to revising the specification. A final standard is unlikely before spring 2006.

On 29 June 2005, the JEDEC Solid State Technology Association and the CEA cosponsored a Discovery Group meeting on RFID Standardization for Supply Chain Management. It was decided at the meeting that identification standards needed to be developed for three areas: (1) form factors of tag assembly, (2) environmental and durability requirements, and (3) consumer electronics products and packages. The first two of these will need to be supported by conformance testing requirements.

Data and System Protocol Standards

Data and system protocol standards are essential for integrating RFID data with logistics AIS. With respect to data handling, RFID differs from bar code in two distinct ways. Unlike bar code symbologies, the basic RFID technology standards (the air interface standards) provide no rules for data encoding. Also, RFID technology allows data to be written and read selectively, which supports an object-based means of data identification.

Existing standards

ISO has developed two standards, see Table 6, for a data protocol that supports selective read and write of data and common encoding rules for a number of air interface standards.

[USTRANSCOM 1995]

Poor quality of DoD transportation and supply data is due to the lack of electronic transmission standards

Increase use of EDI to fill this void

Also, the DoD RFID Policy and DFARS RFID rule require suppliers to provide standard Ship Notice/Manifest Transaction Set messages via Wide Area Workflow for each shipment. These transactions must comply with the Federal Implementation Convention via approved electronic transmission methods (Electronic Data Interchange, web-based, or user-defined format). There still are issues relating to the migration from Military Standard Systems (MILS)/Defense Logistics Standard System to the DLMS, but the DLMS Bridge provides an interim workaround.

Ongoing Work

Work is underway to extend the scope of existing data protocol standards to support additional air interface protocols and sensory information, and to extend the scope of RFID interfaces to business-related decision making applications.

New work proposals have been agreed upon to add a registration authority to some of the data constructs used in ISO/IEC 15961. This registration authority will provide a global control mechanism for adding new Application Family Identifiers (AFIs) that enable fast searching across the air interface, data formats, and object identifier structures to be registered. ISO has also agreed to revise ISO 15961 and 15962 to support the different memory structure and commands that are included in the revision of ISO/IEC 18000-6 (see below).

Table 6. Status of Data and System Protocol Standards

		Existing	Pending
ISO/IEC 15961:2004	Information technology-Radio frequency identification (RFID) for item management Data protocol: application interface Data protocol: data encoding rules and logical memory functions	 ✓ ✓	
ISO/IEC 24752	Automatic Identification and Data Capture Techniques-Radio Frequency Identification (RFID) for Item Management-System Management Protocol		✓
ISO/IEC 24753	Information Technology-Automatic Identification and Data Capture Techniques-Radio Frequency Identification (RFID) for Item Management-Air Interface Commands for Battery Assist and Sensor Functionality		✓

Additionally, there are several industry efforts. The EPCglobal Architecture Framework is a collection of interrelated standards for hardware, software, and data interfaces, together with core services. These standards are mostly still under development. Reva Systems is supporting the definition of the Simple Lightweight RFID Reader Protocol (SLRRP), an open standard for RFID reader control and data transport in Internet Protocol networks. SLRRP will support existing air protocols (such as Auto-ID Class 0/1 and ISO 18000-6b) as well as recently developed standards including EPCglobal UHF Gen 2 and ISO 18000-6c.

Air Interface Standards

Air interface standards are the true technology standards of RFID. The air interface protocol defines the rules by which communications are transacted between the reader and the tag, and the tag and the reader. The standards cover any anti-collision algorithms that might be used to select a single tag from a batch of tags in the interrogation zone. The protocol also covers modulation and bit encoding rules and the essential commands for reading, writing, amending, and locking data. Generally, it does not specify the tag architecture or the memory size available. So, unlike bar code data standards, these standards themselves provide no information on the encoding capacity of the tag. This is left to commercial implementation of the standard.

Each RFID technology has a distinctive air interface protocol, some features of which are related to the frequency that is used. The ISO air interface protocol standards cover frequencies from less than 135 KHz to 2.45 GHz, as detailed below. Some of the standards cover the protocol rules for more than one technology. Among all the different RFID technologies, HF has the most established and commonly used standards, perhaps because 13.56 MHz is a globally available frequency for RFID.

HF for Passive RFID EPCglobal and ISO both have air interface standards for passive RFID in the HF range, see Table 7. The EPCglobal specifications result from work begun under the auspices of the Auto-ID Center at MIT. The Auto-ID Class 0 Specification defines the communications interface and protocol for 900 MHz Class 0 operation. It includes the RF and tag requirements and provides operational algorithms to enable communications in this band. The Auto-ID HF Class 1 Specification provides similar support for 13.56 MHz Class 1 operation.

In addition to not being interoperable, Class 0 and Class 1 standards are incompatible with ISO standards. Each includes a unique and proprietary protocol developed by one of two different suppliers (Matrics, Inc. for Class 0 and Alien Technology Corp. for Class 1) who have placed their respective protocols into the public domain. Neither has been reduced to a standards specification, or ratified by an accredited standards body. They also have problems for international use. Class 0, for instance, sends out a signal at one frequency and receives a signal back at a different frequency within the UHF band; this may be prohibited in Europe (European Union regulations are open to interpretation). In May 2004, EPCglobal halted work on Class 0 and 1 compliance certification.

Currently, DoD is using Class 0 and Class 1 specifications for passive RFID, intending to leverage the marketplace by putting government and commercial sectors on the same standard. As indicated above, this approach carries some risk with respect to international operations. Pacific Basin countries are insisting on the use of ISO standards. Also, World Trade Organization treaties require that ISO standards be employed by signatory nations. Given DoD's intent to migrate to Gen 2 tags and Wal-mart's decision to cease accepting supplies with either class of tag one year after Gen 2 tags become available, Class 0 and Class 1 tags are likely to become obsolete in the near future.

The ISO air interface standard for RFID is the ISO/IEC 18000 series. Parts 2, 3, and 4 address HF and Part 6 the UHF frequency, as shown in Tables 7 and 8.

Table 7. HF Air Interface Standards for Passive RFID

EPCglobal	Auto-ID Class 0 Specification
EPCglobal	Auto-ID HF Class 1 Specification
ISO/IEC 18000:2004	Information technology—Radio frequency identification for item management Part 2: Parameters for air interface communications below 135 kHz Part 3: Parameters for air interface communications at 13,56 MHz Part 4: Parameters for air interface communications at 2,45 GHz

UHF for Passive RFID

Most standards bodies are concentrating on the development of standards for the UHF (860 MHz to 956 MHz) band since the absence of such standards has been a major hurdle to UHF RFID deployments. The delay is largely due to the lack of a globally accepted frequency within the UHF band. As a consequence, industry has started developing products that are either specific to a region or able to work with multiple frequencies.

Here, again, EPCglobal and ISO have competing air interface standards, as shown in Table 8. The EPCglobal document specifies details for 860 to 930 MHz Class 1 operation. The second generation version of the Class 1 specification mentioned earlier was approved by EPCglobal in December 2004. This new standard defines the physical and logical requirements for a passive-backscatter, interrogator-talks-first, RFID system operating in the 860 MHz to 960 MHz frequency range.

Table 8. UHF Air Interface Standards for Passive RFID

EPCglobal	Auto-ID UHF Class 1 860MHz-930 MHz Class 1 Radio Frequency (RF) Identification Tag Radio Frequency and Logical Communication Interface Specification
EPCglobal	Class 1 Generation 2 UHF Air Interface Protocol Standard
ISO/IEC 18000:2004	Information technology—Radio Frequency Identification for Item Management Part 6: Parameters for Air Interface Communications at 860 MHz to 960 MHz

Advantages of Gen 2 Tags

- Open standard
- 96-bit memory plus password in chip
- Smaller size
- High read rates
- Faster read rates
- Better tag identification
- Kill ability
- Encryption
- Global frequency
- Late timing

York (2005) describes several advantages for Gen 2 tags over Class 0 and Class 1 tags. Some of these advantages accrue from it being an open standard. The fact that Gen 2 tags will be available from multiple vendors, for example, is expected to bring prices down and allow equipment from different vendors to be interoperable. Overall performance is likely to improve due to Gen 2's more reliable and faster read rates, better tag identification that should eliminate duplicate reads during multiple tag scans, and the ability to read tags that are late in entering a reader field. The increased memory and reduced size are likely to open up new applications. Security will benefit from built-in password protection, the ability to use a reader to permanently kill a tag, and support for encryption of tag data so that readers do not broadcast data being read. Finally, spread spectrum, frequency-hopping UHF with frequency-modulation capabilities will minimize interference with, or from, other wireless devices

However, the Gen 2 standard only complies with European and Asian UHF radio regulations, not those in other parts of the world. In large part, this was a result of designing the standard to be fast-tracked within ISO so it could be part of the ISO 18000 air interface protocols (although a last-minute disagreement over an AFI has slowed ISO approval). The other concern is an intellectual property (IP) and patent issue that applies to all passive tags and that could drive up tag cost. A group of RFID-related companies is forming an IP licensing consortium that may ameliorate this problem. However, to date, Intermec Technologies, which holds over 140 RFID patents, has not joined the consortium.

For active RFID

There are only two, complementary, ISO air interface standards for active RFID, as shown in Table 9. ISO/IEC 18000-6 is the primary one, with ISO/IEC Technical Report (TR) 24710 adding elementary tag identification functions. A major amendment to ISO/IEC 18000 is currently in process to add the Type C air interface that incorporates the current EPCglobal Class 1 Gen 2 specification. There is some debate as to whether this addition would eclipse two other variations of Part 6, types A (BTG based) and B (Intermec/Philips based), but SC31 disputes this assumption. It is expected that ISO will approve ISO 18000-6c in March 2006.

The future ISO/IEC 18000-6c standard will allow for ISO/IEC 15961-based tag data structures using AFIs in applications defined by agencies other than EPCglobal. Despite the strong recommendation of AIM's REG and others concerned with the rapid progress of Gen 2 through the ISO process, the approved Gen 2 UHF specification makes the use of ISO AFIs optional. This might result in confusion in a supply distribution chain where both ISO and EPC identifiers are used. EPCglobal's AFI Committee believes it has addressed this concern by providing a toggle bit in the header data that identifies whether an AFI or an EPC header follows.

Table 9. Air Interface Standards for Active RFID

ISO/IEC 18000	Information technology—Radio Frequency Identification for Item Management Part 6: Parameters for Air Interface Communications at 860-960 MHz Part 7: Parameters for Air Interface Communications at 433 MHz
ISO/IEC TR 24710	Information technology—Automatic Identification and Data Capture Techniques—Radio Frequency Identification for Item Management

The Smart Active Label Consortium, a non-profit group that promotes the benefits and uses of smart active label technology, has announced that ISO has authorized a new work program under the IEC JTC1 SC31 committee that will add battery-assist and sensor functionality to the existing ISO 18000 series of RFID standards.

Application Support Standards

Application support standards address issues that are relevant to business applications, but fall outside the general communication channel of the air interface, data, and system protocols. Using RFID to track goods in open supply chains is relatively new and ISO, ANSI, and other groups have been working to extend the earlier standards with those that cover the use of RFID with 40-foot shipping containers, pallets, transport units, cases and unique items. These standards are listed in Table 10.

Testing, Compliance, and Health & Safety Standards

Testing Standards Testing standards define procedures that enable the performance of different devices to be measured on a similar and equal basis. The relevant standard is ISO/IEC TR 18046 TR 18046-Information Technology-Automatic Identification and Data Capture Techniques, Radio Frequency Identification Device Performance Test Methods.

Compliance Standards Each of the ISO air interface protocols needs to be supported by a conformance standard. The Technical Reports in the ISO/IEC 18047 series match the air interface protocols of ISO/IEC 18000-n. The standards are published as Technical Reports, because experience of conformance standards is at an early stage of the learning curve. The published set of conformance standards is currently incomplete, but work is ongoing for the other air interface protocols. As procedures stabilize, the Technical Reports will migrate to full international standards. ISO 18047 Parts 2 and 6 are in the draft stage and it is uncertain when they will become final. See Table 11.

Table 10. Status of Application Support Standards

		Existing	Pending
ISO/IEC TR 1800:2004	Information technology-Radio Frequency Identification for Item Management-Application requirements profiles	✓	
ISO 122/104 JWG	Supply Chain Applications of RFID (was ISO/AWI 23389)	✓	
ANS MH10.8.4:2002	Unit Loads and Transport Packages-RFID Tags for Returnable Containers	✓	
ANS/INCITS T6 256-2001	Radio Frequency Identification (RFID) Technology	✓	
ISO/IEC NP TR 24729	Information technology-Radio Frequency Identification for Item Management-Implementation Guidelines Part 1: RFID-enabled Labels Part 2: Recyclability of RF Tags Part 3: RFID Interrogator/Antenna Installation		 ✓ ✓ ✓
ISO DIS 17363	Supply Chain Application for RFID-Freight Containers		✓
ISO DIS 17364	Supply Chain Application for RFID-Transport Units		✓
ISO DIS 17365	Supply Chain Application for RFID-Returnable Transport item		✓
ISO DIS 17366	Supply Chain Application for RFID-Product Packaging		✓
ISO DIS 17367	Supply Chain Application for RFID-Product Tagging		✓

Table 11. Status of Compliance Standards

		Existing	Pending
ISO/IEC TR 18046:2005	Information technology—Automatic identification and data capture techniques—Radio frequency identification device performance test methods	✓	
ISO/IEC TR 18047-2004	Information technology—Radio frequency identification device conformance test methods Part 2: Test Methods for Air Interface Comms. at 120-150 MHz Part 3: Test Methods for Air Interface Comms. at 13,56 MHz Part 4: Test Methods for Air Interface Comms. at 2,45 GHz Part 6: Test Methods for Air Interface Comms. at 860-960 MHz Part 7: Test Methods for Air Interface Comms. at 433.92 MHz (Active)	 ✓ ✓ 	 ✓ ✓ ✓
EPCglobal Class-1 Generation-2	UHF RFID Conformance Requirements Specification	✓	
ISO/IEC NP TR 18047	Information technology—Automatic identification and data capture techniques—RFID device conformance test methods Part 2: Test Methods for Air Interface Communications below 135 KHz Part 6: Test Methods for Air Interface Comms. at 860-960 MHz		 ✓ ✓
ISO/IEC DTR 18047	Information technology—Automatic identification and data capture techniques—RFID device conformance test methods Part 7: Test Methods for Air Interface Communications at 433 MHz		✓

Health & Safety Standards RFID is not the first technology to use radio frequencies and there are well-established standards that address concerns about the possible effects of radio frequency exposure on humans. The primary U.S. standard was developed by the IEEE, and forms the basis for DoDI 6055.11, mentioned in Section 2. There are also two pertinent European standards. These are identified in Table 12.

Table 12. Health & Safety Standards

IEEE Std. C95.1	Safety standard for human exposure to RF Signal, 3 kHz-300 GHz
BS EN 50364	Limitation of human exposure to electromagnetic fields from devices operating in the frequency range 0 Hz to 10 GHz, used in Electronic Article Surveillance (EAS), Radio Frequency Identification (RFID) and similar applications
BS EN 50357	Evaluation of human exposure to electromagnetic fields from devices operating in the frequency range 0 Hz to 10 GHz, used in Electronic Article Surveillance (EAS), Radio Frequency Identification (RFID) and similar applications

Terminology Standards

A technology that is as broad in scope as RFID brings with it a whole set of terminology. The standards listed in Table 13 provide definitions for terms relevant to RFID and general automatic identification and data capture technology.

Table 13. Terminology Standards

ISO/IEC 19762:2005	Information technology-Automatic identification and data capture (AIDC) techniques-Harmonized vocabulary Part 3:-Radio frequency identification (RFID)
ISO 21007: 2005	Gas cylinders-Identification and marking using radio frequency identification technology Part 1: Reference architecture and terminology

Real Time Locating Systems Standards

In many applications, active RFID tags are read as they pass fixed points in a structured process. In RTLS applications, however, tags are read automatically on a fixed, periodic basis, independent of the process that moves the tags. Tag locations may be updated as frequently as every several seconds or as infrequently as every few hours for items that seldom move. (The frequency of updates has implications for the number of tags that can be deployed and the battery life of the tag.) Often these applications operate over large distances. This may necessitate a costlier equipment infrastructure and preclude the ability to write to a tag.

Existing Standards The first RTLS systems, in the late 1990s, were based on emerging WLAN technology. Since that time, several RTLS standards have been developed. U.S.

standards were developed by INCITS T20, but this committee is now in a hold state awaiting output from ISO JTC1/SC31 WG5.

New Standards

ISO JTC1/SC31 WG5 is developing a global RTLS standard based on the earlier INCITS standards. It is anticipated that once the committee has completed its initial work, changes will have to be rolled back into the INCITS standards. ISO has also reached agreement on new work item proposals for RTLS device conformance and performance test methods.

These standards, both existing and under development, are identified in Table 14.

Table 14. Status of RTLS Standards

		Existing	Pending
ANS INCITS 371:2003	Information technology-Real Time Locating Systems (RTLS) Part 1: 2.4 GHz Air Interface Protocol Part 2: 433 MHz Air Interface Protocol Part 3: Application Programming Interface	 ✓ ✓ ✓	
ANS INCITS 371.3:2003	Information technology-Real Time Locating Systems (RTLS)	✓	
ISO/IEC FCD 24730	Information technology-Automatic Identification and Data Capture techniques-Real Time Locating Systems (RTLS) Part 1: Application Programming Interface (API) Part 2: 2.4 GHz air interface protocol		 ✓ ✓
ISO/IEC CD 24730	Information technology-Automatic identification and data capture techniques-Real Time Locating Systems (RTLS) Part 2: 2.4 GHz air interface protocol Part 3: 433 MHz air interface protocol Part 4: Global Locating Systems (GLS)		 ✓ ✓ ✓

Summary of Issues

The major issues with respect to RFID standards are problems with EPCglobal standards (intellectual property, global compatibility, and conflict of interest), frequency spectrum problems, and the potential effect of security requirements on RFID tag costs.

Intellectual Property

Intermec Technologies, an RFID systems provider, claims that the EPCglobal Gen 2 specification contains IP that it has patented. This means that although the standard is royalty-free, companies who offer Gen 2 products will still require a license to use Intermec IP. For now, Intermec has suspended any royalties to encourage adoption of the standard and move the technology forward, but this could change. It is significant that Intermec Technologies, who holds over 140 RFID patents, has not joined the IP licensing consortium. Moreover, when looking at all elements of a RFID system (not just the air interface), there are probably over 4,000 patents that may have a royalty claim, all of which could drive the cost of the tags up.

Global Compatibility Another problem with the Gen 2 specification is that although designed for global compatibility, it is not yet an ISO standard. Until it is an ISO standard, World Trade Organization signatory nations cannot use Gen 2.

The problems with the EPC Class 0 and Class 1 HF air interface standards that DoD has adopted are more serious. Each includes a unique and proprietary protocol developed by one of two different suppliers that have placed their respective protocols into the public domain. Neither approach has been reduced to a standard specification, let alone been ratified by any accredited standards body.

Conflict of Interest The third issue with respect to EPCglobal is that in addition to developing standards, they are selling their services, which implies a potential conflict of interest that would not exist if their standards were international standards. EPCglobal sells subscriptions to its EPCglobal Network, a secure system that connects servers containing information about items identified by EPCs.

Frequency Spectrum Currently, there is no globally accepted frequency within the UHF band, due to restriction in different regions of the world. Recently, Europe adopted new frequency regulations, the downside of which is that the data rate between the reader and the tag is less than in the U.S. It is not yet clear whether the lower data rate in Europe will be a real problem to end users. There is also a concern that active tags might interfere with radar communications.

Potential Effect of Security on Tag Costs Finalization of a standard for electronic seals on freight containers illustrates the potential effect that security requirements could have on tag costs. The standard is being delayed by a number of concerns including the absence of tag security, encryption, and interoperability. The revisions to add these features could end up increasing the cost of an e-seal between 50 and 200 percent. It is not clear that security has been adequately addressed in other RFID standards.

7. Training

An increasing number of commercial companies offer RFID training, or even certifications. This section focuses on training provided by DoD organizations. Many DoD training courses cover supply chain and logistical operations, but training for RFID is less common and focuses mainly on the use of active RFID technology

The DoD RFID CONOPS does not address training. However, in October 2004, ADUSD(SCI) requested the assistance of the Association of Procurement Technical Assistance Centers (APTAC) in OSD's outreach efforts to educate small businesses on RFID technology and DoD implementation plans. To this end, regional DLA PTACs offer RFID training, assistance and one-on-one counseling to DoD suppliers and small businesses at little or no cost. As mentioned in Section 2, several one-day workshops have already been given.

DoD LOG-AIT has been tasked to prepare a multi-level RFID education and training plan for promulgation to all components and agencies. The status of this plan is unknown.

DLA Training

The DLA Active RFID Implementation Plan [DLA 2004] does not mention training. Training in the use of active RFID for ITV is provided, however, in a course offered by DLA Logistics Operations (J-3). This course, Logistics Exchange Training, covers the fundamentals of the supply chain management process, enabling users to recognize different types of systems and where each is applied.

DLA's Passive RFID Implementation Plan [DLA 2004a] states that the DDCs anticipate no significant needs for re-training for receiving functions, other than the addition of material on the edgeware software application. Training for shipping processes will be part of the normal AIS release training and will commence at the time of hardware installation. Alterations in safety procedures and training will be made based upon applicable PM AIT office policies and recommendations. The effects of the adoption of passive RFID technology on the floor and supervisory levels are currently being investigated in order to address possible labor contract issues.

Defense Acquisition University Training

The Defense Acqusition University (DAU) does not offer RFID courses *per se*. A presentation on RFID is available, however, as part of its Rapid Deployment Training Initiative. This initiative is designed to rapidly train the workforce in new initiatives and policy changes. This supports quick notification and training of the acquisition workforce by posting new policy training materials online within hours after policy release and sending DAU training teams to DoD(AT&L) field organizations.

In addition, the DAU Logistics Community of Practice maintains an RFID web site that provides several presentations, references to important RFID reports, and links to Service and component RFID sites.

Air Force Training

According to its RFID implementation plan, the Air Force will determine change requirements for training once the DoD LOG-AIT plan is received. These change requirements will be handled through the AIS program offices.

In general, however, the Air Force anticipates that the use of RFID technology will be incorporated into installation and unit level deployment training. It may also be considered in Utilization and Training Workshops for affected Air Force Specialty codes to determine appropriate training requirements. In addition, as with other AITs, RFID technology will continue to be addressed as part of the ongoing AIT Program Manager Office education mission. These groups are expected to exploit the RFID Solution Center training facilities and expertise.

The Air Force's Cargo Movements Operations System (CMOS) training plan and associated policies will be updated to reflect the new procedures by 2007. An RFID reader training and installation guide for active RFID is expected to be ready by early 2007. Mobile infrastructure training and installation guides for both active and passive RFID are scheduled for early 2007.

The Air Force notes that active RFID use has largely been limited to COCOMs and at nodes supporting COCOM requirements. Institutionalizing RFID technology will require a radical shift in strategy and commitment of resources. Integrating active RFID instruction into AIS training programs will take time. In particular, the Air Force is concerned that passive RFID implementation will require significant training to assure proper use, and there is a risk that the timeframe specified in the DoD RFID Policy will be insufficient.

Army Training

The Army is also waiting for DoD LOG-AIT's education and training plan before making its own plans. Meanwhile, some Army organizations have been provided active RFID training to support its operational use in ITV.

SMPT

The School of Military Packaging Technology (SMPT) teaches four courses that address RFID. SMPT trains approximately 2100 students per year. In addition to Army personnel, attendees come from the Air Force, Marine Corps, and Navy. Over 500 civilians a year also participate. The majority of this training is given by mobile training teams at the DoD Service Schools and centers.

CASCOM

The Army's Combined Arms Support Command (CASCOM) has played a role in many of the current training activities. This training has ranged from overviews of RFID technology to more extended instruction on ITV server data management and analysis. This training has been given to Army personnel and to Marines attending the Basic Logistics/Embarkation Specialist Course at the Marine Corps Combat Service Support School, Logistics Operations School. CASCOM has also provided train-the-trainer instruction to SMPT personnel. The CASCOM ITV Services Web Site provides Active RFID guidebooks and operations guides.

The RF-ITV web site also provides instruction materials, namely a RFID Operations Guide and an ITV Server Guidebook. A new RF-ITV Training CD (Version 1 Rev. 3), in development, will provide training for users of the active RFID Early Entry Deployment Support Kit (EEDSK).

Transportation School The Army Transportation School Integrated Technologies Lab at Fort Eustis, VA, provides training in the use of the Movement Tracking System (MTS) and RFID for ITV, including ITV data analysis. Here, again, training is available to Army and non-Army personnel. The Deployment and Deployment Systems Department offers three courses that cover RFID:

- Unit Movement Officer Deployment Planning Course,
- Transport Officers Basic Course, and
- Mobility Warrant Officer Basic Course.

Navy Training

The NAVY AIT Office also intends to base its training plans on the DoD LOG-AIT education and training plan. At that time, the AIT Office will tailor its plans as necessary to address Navy-unique operating environments and organizational procedures. This effort will include recommendations to the Office of the Chief of Naval Operations, AIT Integration, for: (1) the establishment of a formal curriculum to be developed for inclusion in each appropriate Navy school course, and (2) on-the-job training on RFID, other AIT media and equipment and the operation of associated AISs.

In the interim, the FISC Norfolk Ocean Terminal has developed training guides that are used to provide on-the-job training for workers at the CFS.

Also, the Catalog of Navy Training Courses lists one course specific to RFID, the Amphibious Embarkation Course. This trains students to use current deployment systems (MAGTF Deployment Support System II and Integrated Computerized Deployment Systems), and using bar codes, Military Shipping Labels and active RFID technology for ITV of shipments.

Marine Corps

The Marines Corps AIT CONOPS and Implementation Plan [Marine Corps 2004] states that use of RFID will be covered in training provided for other AIT. The approach being taken for AIT in general is to provide on-site, hands-on training during the installation, upgrade or training of systems using the technology. If classroom training is requested, Marine Corps Bases and Stations are expected to provide the appropriate facilities and standard audio/visual and computing tools. All other training materials will be provided by Marine Corps System Command (MARCORSYSCOM), the operational forces, or the contractor or manufacturer performing the installation or upgrade. This training is only for active RFID since the Marine Corps is not using passive RFID technology at this time.

The standard approach will be a train-the-trainer method. As new technologies or enhancements to current enablers are introduced, manufacturers will provide a combination of training plans and instruction to guarantee the Marine Corps can fully deploy the technology and develop training plans. Simultaneous to the introduction of an upgraded AIS, the Marine Corps Training and Education Command, in conjunction with the manufacturer or systems developer and with functional advocate representation, will develop training plans and curricula to be introduced into the respective MOS schools. This will then allow the Marine Corps to assume the training responsibilities for its personnel.

In order to support this approach, the Marine Corps is adding AIT requirements, including active RFID, to their schoolhouse training standards so that schoolhouse AIS Program Managers will be able to provide mobile training teams.

MARCORSYSCOM MARCORSYSCOM is responsible for coordinating systems training to include that for RFID equipment. This organization will ensure that training is conducted at Formal Learning Centers (FLC) on RFID equipment and its capabilities. MARCORSYSCOM also coordinates training for EEDSKs and New Equipment Training (NET) at each MARFOR. NET will be a supplemental to the FLC training courses. Concurrently, MARCORSYSCOM, in collaboration with Marine Corps Training and Education Command, will establish curricula to be added at the appropriate schools.

Other Training The Marine Corp is adding AIT requirements, including active RFID, to their schoolhouse training standards. Schoolhouse AIS Program Managers will also provide mobile training teams. The Marine Corps schoolhouses are:

- Expeditionary Warfare Training Group Pacific, and
- Marine Corps Combat Service Support Schools-Logistics Operations School

<u>USTRANSCOM Training</u>

The USTRANSCOM RFID Business Plan [USTRANSCOM 2004] states that AMC will determine RFID tactics, techniques, and procedures, and update AMC training instructions. Also, that the Surface Deployment and Distribution Command (SDDC) will train and equip deployment support brigades and terminal transportation battalions with RFID read and write capability to support SDDC unit and ammunition mission requirements at CONUS and OCONUS operations. SDDC will also provide training tools and information on RFID associated with data rich tags and will host transportation and visibility forums to educate, inform, and train personnel on RFID policies and procedures annually, or as needed. The Business Plan gives the following dates:

- AMC training instructions by 4^{th} quarter FY 04,
- SDDC training by 4^{th} quarter 05, and
- SDDC RFID-related training by 4th quarter 05.

8. Outstanding DLA Issues

DLA facilities have been using active RFID tags in operational processes since the mid-1990s. These processes are well understood and mature, but some issues have surfaced regarding the loss of active tag functionality after containers leave DLA depots and the low number of active tags being returned to DLA. As passive tags are only now coming into routine use, there are a larger number of questions that need investigation. First, however, there are some issues that relate to the technology use in general.

General issues

Synchronization of component implementation plans may not be sufficient to ensure a common architecture for the integrated use of active and passive RFID across the Services and other DoD Agencies. Also, there do not appear to be established processes for coordinating with DoD's ongoing logistics transformation and business enterprise efforts.

Needed Action: Determine whether there are conflicts or gaps between RFID implementation plans and ongoing efforts. Recommend actions for DLA to take to resolve such issues, as appropriate.

This second issue is related to the first. Current plans and implementations of RFID technology focus on supply chain nodes, such as depots and PODs. Similarly, reported benefits are largely related to narrowly defined processes. DLA's passive RFID BCA, for example, was based on estimated cost savings in reduced shipping losses, reduced inventory losses, a reduced number of duplicate orders (issuing and transshipping), and reduced labor. These are necessary perspectives, particularly with respect to DLA's operations. It is important, however, that the costs and benefits of the technology are also considered in the wider context of war operations success and mission accomplishment. ROI, for example, can change significantly when viewed from the operational aspect. It is very possible that this additional viewpoint will identify new priorities for the development and application of RFID technology, especially in regard to the needed coordination between systems.

Needed Action: Based on input from DoD end-users, develop metrics that provide insight into how active and passive RFID is impacting mission readiness and operations. Additional input is provided by the RFID objectives and goals stated in the DoD CONOPs.

Standards and efficiency are good reasons to take a market driven approach to RFID adoption, but there is a risk that DoD-specific needs, for example, with regard to munitions safety and environmental performance, will not be met in an optimal fashion. DLA is aware of this risk, as evidenced by its support for the development and evaluation of an active RFID tag that can monitor container security. However, there may be additional cases where RFID users can provide valuable feedback about how the technology could better meet their needs.

Needed Action: ***Solicit input from a sample set of RFID users to identify gaps in RFID technology and potential new research directions. The sample must***

reflect all users potentially impacted by the technology, including DoD suppliers and warfighters.

Active RFID Issues

DLA attaches active tags to all outbound containers and 463L pallets as specified in DoD Policy but has received reports that only roughly 80% of these containers and 463L pallets have active tags with readable data when they arrive at the end customer. Some tags are being lost, but others arrive without batteries or with other damage that has resulted in the loss of tag data. While the loss of a small percentage of tags due to improper attachment or damage during shipping can be expected, the data indicate additional problems. There is anecdotal evidence of some potential causes for the loss of tag functionality, but no thorough accounting.

The loss of in-transit visibility for 20% of containers and 463L pallets is substantial. The data for the number of containers and 463L pallets shipped from DLA's DDCs last year indicate that active tag data was lost for over 25,000 containers or 463L pallets.

Needed Action: Gather information from a sample set of those actively engaged in each step of the supply chain to identify the causes of loss of active tag data functionality. Determine the relative contribution of each cause to identify cost-effective solutions. This investigation should include an assessment of the impact that use of interior-mounted tags may have on the problem.

Passive RFID Issues

The lack of an international standard for frequency allocation for passive UHF RFID poses several problems. DoD is attempting to mitigate these by requiring passive RFID systems to operate across the 860 to 960 MHz range. In addition, some countries require systems to operate at a lower power level than the U.S. The impact of these restrictions on RFID performance is not well understood.

Needed Action: Determine the maturity of readers and tags that operate in the 860 to 960 MHz frequency range and conduct operational trials to determine the performance impact of reduced power levels.

There is concern that the use of passive tags may contaminate packing materials with high levels of potentially dangerous elements. If so, there are personnel hazards that must be mitigated. The disposal of tags and previously tagged materials may also pose an environmental hazard.

The potential problem with respect to personnel safety depends not only on the very large number of packaging cases that DDCs process (both inbound and outbound), but the number of times personnel come in contact with a case and with tags prior to their to being affixed to cases. The current approach to handling the environmental concern is to remove passive tags from the packing materials that are recycled. This is an extra process step that can be time-consuming since the tags can be difficult to remove.

Needed Action: Based on available data, determine the contamination hazard of passive tags as used by the DDCs. Identify approaches for mitigating any risks, in accordance with the requirements of applicable regulations. This analysis should include consideration of the potential positive or negative impact of emerging tag technologies (such as flat film batteries and printed electronics).

The ability to embed passive tags in paper would be a useful capability for assets such as classified maps, facilitating appropriate material handling, and accurate identification and inventory of the assets.

Needed Action: Determine the status of the current technology for embedding passive tags in paper, looking at issues such as stacking papers, the impact of interference in an office (and other environments) and tag performance and costs. Contamination may be an additional concern.

Current passive RFID enabled-processes employ tags whose data is fixed at the factory or when the tag is printed. The ability to subsequently write to tags offers several important benefits. Allowing DoD suppliers to provide an initial data set on supplies that can subsequently be augmented at a DDC is one example of how this capability might be used to provide earlier visibility into the status and condition of warfighter supplies.

Needed Action: Based on the current performance of rewriteable tags, and projected performance improvements over the next five years, provide a cost-benefit analysis of the impact of DLA's use of rewriteable passive tags on war operations success and mission accomplishment.

Packaging suppliers are starting to manufacture packing cases and pallets that have embedded rewriteable passive tags. This is another development that offers the potential to help streamline the receiving and shipping process and impact on war operations success and mission accomplishment.

Needed Action: Based on current technology capabilities and projected developments over the next five years, develop a cost-benefit analysis of the impact of DLA's use of packing cases and pallets with embedded passive tags.

The May 2005 GAO report stated the need for a better understanding of the performance capabilities of passive tags. This type of information will serve several purposes, but its most immediate benefits are likely to lie in: (1) providing guidance for refining business processes so that they make optimal use of the technology, (2) supporting estimation of the potential impact of the increased reliability of Gen 2 tags, and (3) assessing the impact of new products, such as cases with built-in passive tags.

Needed Action: Gather data from ongoing operations to quantify tag performance. With respect to read rates, this data should distinguish between the constraints that technology imposes on read rates (in operational environments) and the effect of improper processes and personnel actions.

References

AIT IPT. December 2005. Radio Frequency Identification Update to the AIT IPT.

Army. December 2004. United States Army Radio Frequency Identification (RFID) Concept of Operations (CONOPS) and Strategic Implementation Plan. Version 2.1. Department of the Army, Deputy Chief of Staff, G4.

Army Science Board. October 2004. *Army Science Board FY 2004 Task Force: Final Report "Intra-Theater Logistics Distribution in the CENTCOM AOR."* Department of the Army Assistant Secretary of the Army, Acquisition, Logistics and Technology.

ATOS. September 2005. Advanced Technology Ordnance Surveillance (ATOS) Advanced Concept Technology Demonstration (ACTD), Military Utility Assessment (MUA), Final Report Brief. Headquarters, U.S. European Command.

CNA. June 2004. *An Examination of Costs and Benefits of Navy RFID Adoption*. CRM D0010265.A2, Center for Naval Analyses.

CONOPS. September 2004. *Department of Defense Concept of Operations (CONOPS) for Radio Frequency Identification (RFID).* Version 2.0. Prepared by the Office of the Secretary of Defense, Supply Chain Integration.

DFARS. September 2005. Defense Federal Acquisition Regulation Supplement; Radio Frequency Identification, Department of Defense 48 CFR parts 211, 212, and 252 [DFARS Case 2004-D011], Final Rule.

DLA. December 2005. Personal communication with DLA, Distribution Planning & Transformation (Chief).

DLB. 28 July 2004. *RFID DLB Decision Brief, document 2541-1*. Available at https://dpo.transcom.mil/dpo/.

DoD. July 2004. *Radio Frequency Identification (RFID) Policy (July 30, 2004).* (Final.) Available at http://www.acq.osd.mil/log/rfid/rfid_policy.htm.

DORRA. June 2005. Department of Defense Business Case Analysis for Passive Radio Frequency Identification. DLA Office of Operations Research and Resource Analysis (DORRA).

FISC. October 2004. Final Report of the passive Radio-Frequency Identification (RFID) Project at the Fleet and Industrial Supply Center, Norfolk, Virginia, Ocean Terminal. Version 8.0.

Government Accountability Office. March 2006. Defense Logistics: More Efficient Use of Active RFID Tags Could Potentially Avoid Millions in Unnecessary Purchases. GAO-06-366R. Washington, DC.

Government Accountability Office. September 2005. Better Strategic Planning Can Help Ensure DoD's Successful Implementation of Passive Radio Frequency Identification. GAO-05-345. Washington, DC.

IDA. 2006. *Use of RFID in Industry's Warehouse Management Processes*. In preparation. Institute for Defense Analyses: Alexandria, VA.

National Council for Air and Stream Improvement. June 2005. Fate of Copper and Silver from RFID Labels During Recycling of OCC and Potential Environmental and Product Implications. Northern Regional Center Kalamazoo, Michigan.

Oat Systems. October 2004. *RFID-GAV Demo Final Report*.

NCASI. June 2005. Fate of Copper and Silver from RFID Labels During Recycling of OCC and Potential Environmental and Product Implications. National Council for Air and Stream Improvement, Northern Regional Center Kalamazoo, Michigan.

NAVSEA. November 2005. Value Chain Prototype Project-Shipboard Implementation Final Report, Smart Stores-Value Chain Prototype (SS-VCP) & Integrated Visibility Manager (IVM) Lite. NAVSEA Warfare Centers, Philadelphia, PA.

NAVSUP. September 2005. Passive Radio Frequency Identification (RFID) Project at the Advanced Traceability and Control (ATAC) Center Norfolk, VA. Naval Supply Systems Command, Naval Inventory Control Point, Norfolk, VA.

NAVSUP. October 2004. Final Report of the Passive Radio Frequency Identification (RFID) Project at the Fleet and Industrial Supply Center, Norfolk, Virginia, Ocean Terminal. Naval Supply Systems Command, Naval Inventory Control Point, Norfolk, VA.

NPC. June 2005. Analysis of Tobyhanna Army Depot's Radio Frequency Identification (RFID) Pilot Program: RFID as an Asset Management Tool. Naval Postgraduate School, Monterey, CA.

RFID. March 2005. *Initial Regulatory Flexibility Analysis of Passive Radio Frequency Identification (RFID)*. Version 1.2. Prepared by the Office of the Under Secretary of Defense for Acquisition Technology & Logistics.

Supplier. December 2005. *U.S. Department of Defense Suppliers' Passive RFID Information Guide*, Version 8.0. Available at http://www.acq.osd.mil/log/rfid/index.htm.

USTRANSCOM. April 2004. U.S. Transportation Command (USTRANSCOM) Radio Frequency Identification (RFID) Business Process Plan. Available at https://business.transcom.mil/J5/j5p/RFIDBPP.pdf.

USTRANSCOM. February 2005a. USTRANSCOM RFID Monthly Telecon, 3 February 2005.

USTRANSCOM. January 2005b. USTRANSCOM Update Briefing to the DoD AIT IPT, 15 January 2005.

Acronyms and Abbreviations

ACTD	Advanced Concept Technology Demonstration
ADUSD	Assistant Deputy Under Secretary of Defense
AFB	Air Force Base
AFI	Application Family Identifier
AIM	Automatic Identification and Mobility
AIS	Automated Information System
AIT	Automated Identification Technology
AMC	Air Mobility Command
ANSI	American National Standards Institute
ANS	American National Standard
APTAC	Association of Procurement Technical Assistance Centers
ASC	Accredited Standards Committee
ASN	Advance Shipping Notice
AT&L	Acquisition, Technology, and Logistics
ATAC	Advanced Traceable and Control
ATOS	Advanced Technology Ordnance Surveillance
BCA	Business Case Analysis
BPWG	Business Process Working Group
CAGE	Commercial and Government Entity
CASCOM	Combined Arms Support Command
CEA	Consumer Electronics Association
CFS	Container Freight Station
CHMS	Container Health Monitoring System
CMB	Contact Memory Button
CMOS	Cargo Movements Operations System
CNA	Center for Naval Analyses
COCOM	Combatant Commander
CONOPS	Concept of Operations
CONUS	Continental United States
DDC	Defense Distribution Center
DDJC	Defense Deport San Joaquin, CA
DDNV	Defense Depot Norfolk, VA
DDSP	Defense Depot Susquehanna, PA

DeCA	Defense Commissary Agency
DFARS	Defense Federal Acquisition Regulation Supplement
DLA	Defense Logistics Agency
DLB	Defense Logistics Board
DLE	Defense Logistics Executive
DoD	Department of Defense
DoDAAC	DoD Activity Address Code
DoDI	DoD Instruction
DORRA	DLA Office of Operations Research and Resource Analysis
DUSD	Deputy Under Secretary of Defense
E3	Electromagnetic Effects on the Environment
ECC	European Community Council
EEDSK	Early Entry Deployment Support Kit
EMI	Electromagnetic Interference
EMU	Expeditionary Medical Unit
EPC	Electronic Product Code
eRMS	Electronic Retrograde Movement System
ETSI	European Telecommunications Standards Institute
FCC	Federal Communications Commission
FHSO	Fleet Hospital Support Office
FIPS	Federal Information Processing Standard
FISC	Fleet and Industrial Supply Center
FLC	Formal Learning Center
FTTS	Future Tactical Truck System
FY	Fiscal Year
GAO	Government Accountability Office
GAV	Global Asset Visibility
Generation 2	Gen 2
HERF	Hazardous Electromagnetic Radiation on Fuels
HERO	Hazardous Electromagnetic Radiation to Ordnance
HERP	Hazardous Electromagnetic Radiation on Personnel
HF	High Frequency
ICT	Information and Communication Technologies
IDE	Integrated Data Environment
IEC	International Electrotechnical Commission
INCITS	InterNational Committee for Information Technology Standards
IP	Intellectual Property
IPE	Individual Protective Equipment
IPT	Independent Product Team

ISO	International Organization for Standards
ITV	In-Transit Visibility
IUID	Item Unique Identification
IV&V	Independent Validation and Verification
IWG	Implementation Development and Oversight Working Group
JSLIST	Joint Service Lightweight Integrated Suit Technology
JTAV	Joint Total Asset Visibility
JTC	Joint Technical Committee
L/LSM	Logistics and Materiel Readiness, Logistics System Management
LCAV	Logistics Center Customer Asset Visibility
LOG-AIT	Logistics-Automatic Identification Technology
LM&R	Logistics and Materiel Readiness
LTA	Logistics Transformation Agency
MARCORSYSCOM	Marine Corps System Command
MEMS	Micro-Electro-Mechanical Systems
MESKO	Medical Sets Kits and Outfit
MHI	Material Handling Industry
MPC	Material Processing Center
MPF	Maritime Pre-Positioning Force
MIL-STD	Military Standard
MILSTRAP	Military Standard Requisitions and Accounting Procedure
MILSTRIP	Military Standard Requisitions and Issue Procedure
MRE	Meals, Ready to Eat
MSV	Manuever Sustainment Vehicle
MTS	Movement Tracking System
MUA	Military Utility Assessment
NCASI	National Council for Air and Stream Improvement
NAVSEA	Naval Surface Warfare Center
NAVSUP	Naval Supply Systems Command
NBCD	Nuclear, Biological, and Chemical Defense
NCASI	National Council for Air and Stream Improvement
NFELC	Naval Facilities Expeditionary Logistics Center
NET	New Equipment Training
NoMaDD	Node Management and Deployable Depot
NSC	Natick Soldier Center
NTAV	Naval Total Asset Visibility
OCONUS	Outside Contiguous United States
OIF	Operational Iraqi Freedom
OSD	Office of the Secretary of Defense

OTMS	Ocean Terminal Management System
OUSD	Office of the Under Secretary of Defense
PACOM	Pacific Command
PAL	Precision Asset Location
PCH&T	Packing, Crating, Handling & Transportation
PEO EIS	Program Executive Office, Enterprise Information Systems
PM J-AIT	Product Manager Joint-Automatic Identification Technology
POD	Port of Debarkation
POD	Proof of Delivery
POE	Port of Embarkation
POM	Program Objective Memorandum
PTAC	Procurement Technical Assistance Center
RAPID	RFID Active Passive Intermodal Project
RF	Radio Frequency
RF-ITV	Radio Frequency-Intransit Visibility
RFID	Radio Frequency Identification
RFMSL	RFID Tag Military Shipping Label
ROI	Return on Investment
RSS	Ready Service Spares
RTLS	Real Time Locating Systems
SC	SubCommittee
SCI	Supply Chain Integration
SDDC	Surface Deployment and Distribution Command
SGTIN-96	Serialized Global trade Item Number
SLRRP	Simple Lightweight RFID Reader Protocol
SMPT	School of Military Packaging Technology
SSCC-96	Serialized Container Code
SSP	Strategic Systems Program
TC-ERM	EMC and Radio Spectrum Matters Committee
TDC	Theater Distribution Center
TOA	Table of Allowance
TR	Technical Report
TRA	Technology Readiness Assessment
TWG	Technical Working Group
UGR	Unitized Group Rations
UHF	Ultra High Frequency
UII	Unique Item Identifier
USAF	U.S. Air Force
USAMMCE	U.S. Army Medical Materiel Center-Europe

USEUCOM	U.S. European Command
USCENTCOM	U.S. Central Command
USD	Under Secretary of Defense
USTRANSCOM	U.S. Transportation Command
UWB	Ultra Wide Band

Appendix A. Glossary of RFID Terms

The following descriptions are taken mainly from the *RFID Journal*'s *Glossary of RFID Terms*, available at http://www.rfidjournal.com/article/articleview/208.

Active tag: An RFID tag that has a transmitter to send back information, rather than reflecting back a signal from the reader, as a passive tag does. Most active tags use a battery to transmit a signal to a reader. However, some tags can gather energy from other sources. Active tags can be read from 300 feet (100 meters) or more and typically cost over $20.

Antenna: The tag antenna is the conductive element that enables the tag to send and receive data. Passive, low- (135 kHz) and high-frequency (13.56 MHz) tags usually have a coiled antenna that couples with the coiled antenna of the reader to form a magnetic field. UHF tag antennas can be a variety of shapes. Readers also have antennas which are used to emit radio waves. The RF energy from the reader antenna is "harvested" by the antenna and used to power up the microchip, which then changes the electrical load on the antenna to reflect back its own signals.

Anti-collision: A general term used to cover methods of preventing radio waves from one device from interfering with radio waves from another. Anti-collision algorithms are also used to read more than one tag in the same reader's field.

Backscatter: A method of communication between passive tags (ones that do not use batteries to broadcast a signal) and readers. RFID tags using backscatter technology reflect back to the reader the radio waves from a reader, usually at the same carrier frequency. The reflected signal is modulated to transmit data.

Battery-assisted tag: These are RFID tags with batteries, but they communicate using the same backscatter technique as passive tags (tags with no battery). They use the battery to run the circuitry on the microchip and sometimes an onboard sensor. They have a longer read range than a regular passive tag because all of the energy gathered from the reader can be reflected back to the reader. They are sometimes called semi-passive RFID tags.

Carrier frequency: The main frequency of a transmitter, or RFID reader, such as 915 MHz. The frequency is then changed, or modulated, to transmit information.

Chipless tag: An RFID tag that doesn't depend on a silicon microchip. Some chipless tags use plastic or conductive polymers instead of silicon-based microchips. Other chipless tags use materials that reflect back a portion of the radio waves beamed at them. A computer takes a snapshot of the waves beamed back and uses it like a fingerprint to identify the object with the tag. Companies are experimenting with embedding RF reflecting fibers in paper to prevent unauthorized photocopying of certain documents. Chipless tags that use embedded fibers have one drawback for supply chain uses—only one tag can be read at a time.

Class 0: Initial EPC standard for factory-programmed tags. These tags come from the factory with a preset number that cannot be changed. Class 0 is based on protocols initially invented by Matrics, Inc.

Class 1: Initial EPC standard for write-once tags. These tags are designed to be written with data once at the time the tag is applied to an object, quite often in a printer when a tag label is printed to apply to a box.

Commissioning: This term is sometime used to refer to the process of writing a serial number to a tag (or programming a tag) and associating that number with the product it is put on in a database.

Electronic Product Code (EPC): A serial, created by the Auto-ID Center, that complements barcodes. The EPC has digits to identify the manufacturer, product category, and the individual item.

Frequency: The number of repetitions of a complete wave within one second. 1 Hz equals one complete waveform in one second. 1KHz equals 1,000 waves in a second. RFID tags use low, high, ultra-high and microwave frequencies. Each frequency has advantages and disadvantages that make them more suitable for some applications than for others.

Frequency hopping: A technique used to prevent readers from interfering with one another. In the United States, UHF RFID readers actually operate between 902 and 928 MHz, even though it is said that they operate at 915 MHz. The readers may jump randomly or in a programmed sequence to any frequency between 902 MHz and 928 MHz. If the band is wide enough, the chances of two readers operating at exactly the same frequency is small. The UHF bands in Europe and Japan are much smaller so this technique is not effective for preventing reader interference.

Generation 2: The standard ratified by EPCglobal for the air-interface protocol for the second generation of Class 1, read-write EPC technologies.

High-frequency (HF): From 3 MHz to 30 MHz. HF RFID tags typically operate at 13.56 MHz. They typically can be read from less than 3 feet away and transmit data faster than low-frequency tags. But they consume more power than low-frequency tags.

Interrogate: See Reader.

Low-frequency: From 30 kHz to 300 kHz. Low-frequency tags typical operate at 125 kHz or 134 kHz. The main disadvantages of low-frequency tags are they have to be read from within three feet and the rate of data transfer is slow. But they are less subject to interference than UHF tags.

Memory: The amount of data that can be stored on the microchip in an RFID tag.

Modulation: Changing the radio waves traveling between the reader and the transponder in ways that enable the transmission of information. Waves be changed in a variety of ways that can be picked up by the reader and turned into the ones and zeroes of binary code. Waves can be made higher or lower (amplitude modulation) or shifted forward (phase modulation). The frequency can be varied (frequency modulation), or data can be contained in the duration of pulses (pulse-width modulation).

Null spot: Area in the reader field that doesn’t receive radio waves. This is essentially the reader’s blind spot. It is a phenomenon common to UHF systems.

Passive tag:	An RFID tag without a battery. When radio waves from the reader reach the chip's antenna, the energy is converted by the antenna into electricity that can power up the microchip in the tag. The tag is able to send back information stored on the chip. Today, simple passive tags cost from U.S. 20 cents to several dollars, depending on the amount of memory on the tag and other features.
Power level:	The amount of RF energy radiated from a reader or an active tag. The higher the power output, the longer the read range, but most governments regulate power levels to avoid interference with other devices.
Read:	The process of retrieving data stored on an RFID tag by sending radio waves to the tag and converting the waves the tag sends back into data.
Reader:	A device used to communicate with RFID tags. The reader has one or more antennas, which emit radio waves and receive signals back from the tag. The reader is also sometimes called an interrogator because it "interrogates" the tag.
Reader:	The reader communicates with the RFID tag via radio waves and passes the information in digital form to a computer system.
Reader field:	The area of coverage. Tags outside the reader field do not receive radio waves and can't be read.
Read-only tags:	Tags that contain data that cannot be changed unless the microchip is reprogrammed electronically.
Read range:	The distance from which a reader can communicate with a tag. Active tags have a longer read range than passive tags because they use a battery to transmit signals to the reader. With passive tags, the read range is influenced by frequency, reader output power, antenna design, and method of powering up the tag. Low frequency tags use inductive coupling, which requires the tag to be within a few feet of the reader.
Read rate:	Often used to describe the number of tags that can be read within a given period. The read rate can also mean the maximum rate at which data can be read from a tag expressed in bits or bytes per second.
Read-write tag:	An RFID tag that can store new information on its microchip. These tags are often used on reusable containers and other assets. When the contents of the container are changed, new information is written to the tag. Read-write tags are more expensive than read-only tags.
Semi-passive tag:	Similar to active tags, but the battery is used to run the microchip's circuitry and not to broadcast a signal to the reader. Some semi-passive tags sleep until they are woken up by a signal from the reader, which conserves battery life. Semi-passive tags can cost a dollar or more. These tags are sometimes called battery-assisted tags.
Sensor:	A device that responds to a physical stimulus and produces an electronic signal. Sensors are increasingly being combined with RFID tags to detect the presence of a stimulus at an identifiable location.
Smart label:	A generic term that usually refers to a barcode label that contains an RFID transponder. It's considered "smart" because it can store information, such as a unique serial number, and communicate with a reader.
Tag:	A microchip attached to an antenna that is packaged in a way that it can be applied to an object. The tag picks up signals from and sends signals to

a reader. The tag contains a unique serial number, but may have other information, such as a customers' account number. Tags come in many forms, such smart labels that can have a barcode printed on it, or the tag can simply be mounted inside a carton or embedded in plastic. RFID tags can be active, passive or semi-passive.

Tag data: Data stored in the memory area of a tag.

Transponder: A radio transmitter-receiver that is activated when it receives a predetermined signal. RFID transponders come in many forms, including smart labels, simple tags, smart cards and keychain fobs. RFID tags are sometimes referred to as transponders.

Ultra-high frequency (UHF): From 300 MHz to 3 GHz. Typically, RFID tags that operate between 866 MHz to 960 MHz. They can send information faster and farther than high- and low-frequency tags, but radio waves don't pass through items with high water content at these frequencies. UHF tags are also more expensive than low-frequency tags, and use more power.

REPORT DOCUMENTATION PAGE					*Form Approved OMB No. 0704-0188*

1. REPORT DATE (DD-MM-YY) April 2006	2. REPORT TYPE Study	3. DATES COVERED (From – To)

4. TITLE AND SUBTITLE Selected Issues in DoD's Radio Frequency Identification (RFID) Implementation	5a. CONTRACT NUMBER DASW01-04-C-0003 W74V8H-05-C-0042
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBERS
6. AUTHOR(S) Christine Youngblut, Sarah H. Nash, Michael S. Nash, Task Leader	5d. PROJECT NUMBER
	5e. TASK NUMBER DE-5-2452
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESSES Institute for Defense Analyses 4850 Mark Center Drive Alexandria, VA 22311-1882	8. PERFORMING ORGANIZATION REPORT NUMBER IDA Paper P-4094
9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES) DLA 8725 John J. Kingman Road, Stop 6233 Ft. Belvoir, VA 22060-6221	10. SPONSOR'S / MONITOR'S ACRONYM DLA
	11. SPONSOR'S / MONITOR'S REPORT NUMBER(S

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; unlimited distribution: 13 March 2007.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

This report describes the full scope of the Department of Defense (DoD) Radio Frequency Identification (RFID) activities with the purpose of identifying RFID-related issues specific to the Defense Logistics Agency (DLA). It summarizes DoD Components' status in implementing DoD RFID policy requirements, new DoD uses of active RFID, and progress in the use of passive RFID in the DoD supply chain. The report also addresses relevant standards and RFID training activities. There are several issues for DLA relating to the use of both active and passive RFID. These range from programmatic concerns regarding the need for a common RFID system architecture to practical concerns about the performance impact of reduced power levels. The report recommends actions that may allow potential benefits of emerging RFID technology to streamline DLA operations.

15. SUBJECT TERMS

Radio Frequency Identification (RFID), IT-enabled Logistics Technology, Logistics Enterprise.

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON Mr. John Christensen
a. REPORT Unclassified	b. ABSTRACT Unclassified	c. THIS PAGE Unclassified	Unlimited	83	19b. TELEPHONE NUMBER (Include Area Code) (703) 767-1463