An Introductory Analysis of Auto-ID Applications in the Department of Defense Supply Chains

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Abstract— **This article provides an introductory analysis of the applicability of the Auto-ID Centers Network Physical World EPC system within the supply chains of the U.S. Department of Defense (DoD). The DoD is a large, complex military organization with a broad range of responsibilities to protect U.S. interests around the world. In discharging these responsibilities, the DoD must manage and transport large amounts of equipment and supplies in support of a wide range of military operations. Keeping track of this material is a difficult task involving real time inventory visibility through the supply chain.**

Recognizing the importance of accurate information as a prerequisite of readiness, the DoD set forth in the Joint Vision 2020 report a goal of implementing a real-time, web-based information system providing total asset visibility by FY04. This is a challenging goal given the unique characteristics of the DoD supply chain that includes 1) emphasis on readiness, 2) long span, 3) large variety of items, 4) unstable demand, 5) moving end points, 6) emphasis on reliability and maintenance and 7) concern over detection.

Given this unique set of characteristics, the DoD supply chain differs in many respects as compared to the civilian supply chain. The most effective strategy in managing the DoD supply chain is to adopt a single standard for automatic identification that includes passive, semi-passive, and active tag technologies combined with an information backbone that can handle large amounts of data. The Auto-ID Center's EPC system technology has these capabilities along with being a standard that is universally accepted within the commercial world. By some accounts, a single standard for identification would save billions of dollars annually for the DoD.

Given the Auto-ID Center's EPC system technology as a base, there are a number of areas for potential EPC applications. A few examples include:

1. Track and trace Using mass serialization, tracking is the ability to see the current location of shipments through the DoD supply chain. EPC system technology provides the ability to track items in real-time and to trace historical information for a uniquely identified item.
2. Item Information Unique identification allows the ability to rapidly look-up information about a particular item during its lifetime. This information might include the supplier producing the product, environmental storage conditions, maintenance performed, and current list of components.
3. Military and Civilian Interface The DoD procures large amounts of material from private industry. EPC system technology provides a common standard for information exchange between the DoD and private contractors. This level of communication will produce a more integrated supply chain, ultimately leading to a higher level of readiness and lower cost.
4. Predictive Maintenance The military places a great deal of emphasis on maintenance of equipment to guarantee readiness. EPC system technology has great potential to make the maintenance process more efficient and to optimize service parts inventory.
5. Accurate Inventories All planning starts with an estimate of material available. The ability of the EPC system to provide accurate real-time visibility will give military planners unparalleled details needed to make decisions.
6. Budgeting Given accurate, real-time inventories, the process of budgeting will be improved.

Success in warfare increasingly depends on accurate information and sound logistical planning. Accurate information is required for both battlefield operations and the support functions responsible for ensuring enough supplies exist at the right location to support the combat troops. EPC system technology will play an important role in providing information through open standards combined with unprecedented total asset visibility.

I. Introduction

The U.S. Department of Defense (DoD) is a large, complex military organization charged with protecting the U.S. territories and interests worldwide. More than 1.4 million active duty personnel execute the military activities [7] with millions more civilian personnel supporting the activities of the DoD. Personnel, equipment, and supplies are strategically located to enable the DoD to effectively and efficiently carry out its duties. Consequently, the DoD has permanent and temporary military bases and operations located around the world.

Given the nature of DoD activities, a wide range of products, materials, and supplies must be distributed to all bases and operations locations in a timely manner to guarantee the readiness of the military personnel to perform their duties. Large volumes of supplies and equipment are purchased, maintained, and transported between bases and operations locations every year with the DoD maintaining an inventory level valued at more than US$80.5 billion. Managing this inventory is a large-scale systems problem that is complicated by the differences in systems used by the various military branches and organizations within the DoD. Currently, the Defense Research Projects Agency (DARPA) is managing the Advanced Logistics Program (ALP). ALP is designed to develop and implement technologies that improve the effectiveness of logistical planning for warfare. The most important input into all logistics and ALP-based systems is accurate, real-time information about the location and availability of all materials, supplies, and equipment needed to support military missions. This information is critical for overall planning at the strategic, tactical, and operational levels.

The absolute requirement for asset visibility to enable efficient and effective supply chain management is recognized in Joint Vision 2020 (JV2020) [8]. JV2020 devotes a

special section to the emerging role of logistics in modern warfare. In this section, the document states that the goal of the military logistics is the development of "...a real-time, web-based information system providing total asset visibility." The target for implementation of these total asset visibility technologies is FY 04.

The Auto-ID Center has developed, implemented, and tested in a large-scale supply chain application the Networked Physical World EPC system that enables the automatic identification and location of all objects, thereby, providing total asset visibility [4]. Through a combination of mass serialized item identification with the Electronic Product Code (EPC), radio frequency identification (RFID) systems, and sophisticated data and information handling capability, Auto-ID technology links physical objects to information accessible through the Internet or a secured Intranet. The Electronic Product Code enables the unique identification of every item, aggregation, and grouping. An EPC is a representation of an Electronic Product Code that acts as a pointer to networked information about its associated object. With the Auto-ID Center's EPC system, complete real-time inventory visibility is possible.

The EPC system is being adopted as a standard within the commercial industries [3]. The Auto-ID Center's technology is applicable to the military as well. This enables a military-commercial interface where all military suppliers use the same standardized system to identify objects. The use of the Auto-ID Center's system will lead to a revolutionary improvement in readiness for war by providing the DoD with unprecedented visibility and control of the supply chain.

In the remainder of this document, we examine the unique characteristics of the DoD's supply chains and the applicability of the Auto-ID Center's Networked Physical World EPC system to enabling these supply chains to operate more efficiently and effectively. The DoD's supply chains have many unique characteristics due to the DoD's primary emphasis on troop readiness instead of cost as experienced in the commercial supply chains. Section II discusses these unique aspects of the military supply chain. Section III examines the historical problems experienced in the DoD supply chains due to lack of asset visibility. Section IV reviews some of the existing RFID-based applications being performed or examined within the DoD. Section V examines how the Networked Physical World EPC system can positively impact the DoD's supply chains. Finally, we draw the relevant conclusions in Section VI.

II. Unique Characteristics of the DoD Supply Chain

In many areas, the supply chains within the DoD are similar to the supply chains of their commercial suppliers. This is because many of the products and supplies contained within the DoD supply chains are commercially available. However, the military supply chain is optimized primarily for troop readiness, whereas the commercial supply chain is optimized primarily for cost and service. These differences in optimization criteria, as well as the unique items contained within the DoD supply chains only, have lead to a number of unique characteristics for the DoD supply chains. We review the most important of these characteristics below.

Readiness: The metric for military supply chain success is readiness for war. Knowing the location and status of all materials needed to support operations is an essential component of readiness.

Long Span: War is an international activity requiring long lines of supply to support operations. These supply lines extend from the suppliers to the front line troops. Without an automated identification technology that provides real time visibility, it is extremely difficult to maintain accurate knowledge of supply chain wide inventories.

Variety of Items: Military operations require a large number of distinct items ranging from everyday supplies of food and clothing to specialized equipment. This creates the necessity to categorize items where each category, or class, has a different standard for inventory accuracy and visibility.

Unstable Demand: Military demand is often variable and unpredictable [9]. Conflicts can arise anywhere in the world at anytime. When a conflict occurs, demand for supplies increases dramatically. Existing stockpiles of material are depleted quickly. Accurate inventories are a necessity to maintain readiness in the presence of variable demand.

Moving End Points: The end-points of the military supply chain move as the operations are initiated, move forward, and are either terminated or transformed, creating additional complications for transportation and inventory management.

Priority: The military supply chain operates on priorities with unit commanders determining urgency of need.

Equipment Reliability and Maintenance: Military operations take place in a number of harsh environments. Under battle conditions, it is important that all identification technologies work effectively and that maintenance costs are low.

Detection: In a theater of battle, the armed forces must always be vigilant in not divulging positional information, giving advantage to the enemy.

All of these characteristics set military supply chains apart from standard practice in the commercial world. Furthermore, the problems that result from these characteristics are due in large part to the lack of inventory visibility within the existing DoD supply chains. As such, the application of automated identification systems to enable total asset visibility will eliminate or significantly reduce the impact of these problems. The unique characteristics of the supply chains will require customization of the automated identification systems to the peculiar aspects of the DoD supply chains.

The following section outlines several classic military supply chain problems resulting from a lack of inventory visibility.

III. Historical Supply Chain Issues

Published research during the past twenty years documents several problems in military logistical operations that relate to inaccurate inventories. These are just a few of the problems where the Auto-ID Center's EPC system can provide great benefit through improved inventory visibility.

A. General Inventory Management

A study by Alexander in 1985 [1] found that improper inventory records contributed to the problem of miscalculating order quantities. In addition, delays in shipping create uncertain transit times. Faced with little supply chain visibility, military planners have no choice but to over-order in an attempt to deal with uncertainty. This leads to invalid priorities, excess inventory, and bottlenecks in transportation. Accurate, real-time inventory throughout the supply chain would improve visibility and reduce over ordering.

B. Repair and Maintenance

Any large-scale repair operation is complex because it is difficult to predict demand for service parts. In military repair operations, expensive parts are given high priority and, when shipped from one location to another, usually arrive quickly. However, the lower priority inexpensive parts often are critical to complete the repair. The lower priority that these parts usually carry often causes them to experience shipping delays. In turn, this causes a delay for the entire repair cycle [5]. In some cases, military planners increase total fleet size to compensate for lengthy repairs [2].

C. Readiness and Mobility

The best metric for determining the effectiveness of the military supply chain is readiness and mobility. The combat forces must be ready to engage in a conflict, and they must be able to move to the conflict location to engage in the conflict. Readiness of the troops is partly determined by the readiness of their equipment and mobile maintenance facilities. Proper repair and maintenance are required for equipment readiness. Mobility is primarily determined by the quantity of goods needed to be moved and the number of transport vehicles available. In general, the smaller the inventory required to travel with a force the greater its mobility. Accurate knowledge of inventory quantities and locations enables the logistics support systems to transport a greater quantity of items; thereby reducing the inventory of and increasing the mobility of the forward positioned troops.

D. Track and Trace

The limited asset visibility obtained without a ubiquitous automated identification technology prevents the tracking of assets as they move through the supply chain. Similarly, this limited visibility prevents the tracing of objects back through the supply chain. The inability to track and trace individual items throughout the supply chains negatively impacts all supply chain related applications including repair and maintenance as described above and prevents applications such as the identification of prone to failure parts and assemblies and the ability to perform predictive maintenance.

These general problems have led to past and present inefficiencies within the military. In response, the DoD has initiated several test programs to understand the capabilities of automated identification technologies. The next section summarizes published reports on a few active projects.

IV. Existing RFID Technology in DoD

To date, the DoD has made preliminary investments in research and development of RFID systems to improve security, cargo visibility, inventory management, product tracking, and quality control. This section reviews a small number of these applications and RFID systems.

A. Security

Automatic Vehicle Identification (AVI) is a project to enhance security at access control points. The US Army has hired Transcore, inc. to test access control at Fort Monmouth, NJ using passive UHF (ultra high frequency) eGo RFID tags. Transcore provides technology-based services and products that enable its customers to manage ground transportation systems.

Testing of eGo tags began in November 2002. Vehicles with proper security clearances were equipped with eGo tags on their windshields. As vehicles approach the research center, they encounter a simple tilt-arm gate. An RFID reader identifies the vehicle and the gate opens. The car then proceeds to a common access reader and the driver is identified using established, non-RFID procedures.

Technology used for this test includes the eGo windshield tag and the eGo 2210 reader. The tag is a sticker that is thin and applies to the windshield of a vehicle. It is an RF-programmable, passive tag technology that operates in the 902MHz-928MHz frequency range. The tag is tamper resistant and can withstand extreme temperatures, sunlight, humidity, and vibration. Approximate cost of the tag is US$10. The tags contain a 64-bit ID and 1024 bits of memory. Testing is still in progress.

B. Cargo Asset Visibility and Security

The DoD and Savi Technology are working on two projects, Smart and Secure Tradelines (SST) and Total Asset Visibility (TAV).

SST aims to place tags on steamship containers prior to shipment. The tag will provide information about the container's journey when it arrives at a port. The tag records any activity, such as the breaking of security measures, during transit. It also provides detailed information about what should be inside the container. A weight check can verify this information at the port of entry into the United States.

TVA was created by Savi as an initiative to track cargo containers in an attempt to have knowledge of location at any time. The system is based on Savi's Universal Data

Appliance Protocol (UDAP), which allows for integration of devices such as RFID and GPS.

C. HAZMAT Recognition

The Defense Logistics Agency (DLA) has organized a complete test of Advanced HAZMAT Rapid Identification, Sorting, and Tracking (AHRIST). Currently, no system exists that automatically alerts personnel prior to an arrival of HAZMAT material. The objective of this project is to enable the track and trace of HAZMAT materials through the supply chain.

Operating frequencies used in testing include 862MHz-870MHz in Europe, Africa, and USSR, 902MHz-928MHz in North and South America, and 2.45GHz in the Pacific and Asia. The Micron Technologies tags used in the test have a read range of 10 feet in North and South America and 128 bytes of storage.

D. Tracking and Product Information

On another project, the DoD is working with Symbol Technologies, Zebra Technologies, and Texas Instruments in material tracking applications. In 1999, Symbol Technologies was awarded a 5-year, US$248 million contract for automated identification technologies and services. Projects include deployment of materials and personnel throughout the world, tracking supplies through global distribution centers, and advance identification of military personnel. The tracking uses the Nato Stock Number System (NSN) where 1.8 million line items can be distinctly identified. There are currently two 15-meter RF towers in the largest distribution center in Sydney, Australia. The computer system interface includes the use of the IBM ES9000 Series mainframe running Mincom's Management information System (MIMS). The project tracks goods receiving, spot-checking, and special care during distribution such as batch number, shelf life, expiration date, and repairable or non-repairable categories.

E. MRE Quality Control

MRE Quality Control is currently being tested in the Natick, Massachusetts field site. Hardware developed by Savi Technologies is used to track inventory at supply points at the container level. Savi identification tags are used at the container level only. The primary application of these tags is automatic inventory updating of the containers. Low-cost passive and semi-passive RFID tags developed by Alien Technologies are being used to identify MRE cases and pallets respectively. This project also includes the use of the Auto-ID Center's technology to track shelf life, including the environmental conditions (temperature, humidity, and vibration) under which MREs are stored [6].

These are just a few examples of how automated identification can solve practical problems existing within the DoD's supply chains. In the following section, we outline areas where the Auto-ID Center's EPC system can be used within the DoD.

V. HOW AUTO-ID AND DOD COME TOGETHER

The important element missing from current DoD testing of RFID systems is standardization. A standard system for automated identification across the entire DoD will facilitate inventory management and related applications; thereby creating increased readiness at a reduced cost. Some estimate that the DoD would save billions of dollars by adopting a single standard.

Several possibilities for joint research between the Auto-ID Center and the DoD exist using the open standards of Auto-ID Center.

A. Track and Trace

The EPC system, through mass serialization and the ONS database, allows for real-time tracking of supplies using a single technology. In the case of maintenance and spare parts, a standardized system of inventory management will give visibility to the location of parts. Maintenance and repair becomes more efficient and applications such as predictive maintenance become possible.

B. Product Information

The EPC read by a reader is a unique identifier pointing to a database holding all information about an item. A current UPC holds only limited information regarding the manufacturer and product name. With the EPC system, any military planner along the supply chain can access detailed information, including suppliers of each component of the product, transportation methods, and environmental storage conditions for the item throughout its lifetime. Military planners will have a great deal more information about an item, allowing them to make better decisions.

C. Military and Civilian Interface

With a standardized system, the DoD can be integrated with the civilian world. Currently, over 100 leading companies are sponsors of the Auto-ID Center. And, it is likely that the current Auto-ID Center members will implement the EPC system in the near future.

By using the same standard as industry, the DoD will be able to communicate with commercial vendors, gaining direct visibility into inventory at civilian locations. An active military/civilian interface also reveals the opportunity for collaboration between vendors and military planners in enhancing readiness for war. Precise inventory levels by version are possible with the EPC system. Civilian warehouses can assist the military in stockpiling to ensure supply for a number of war scenarios. This might take the form of carrying "warm" inventories that are reserved for military operations, yet continue to cycle into normal shipments. This practice would reduce loss resulting from exceeding shelf life limits. Using inventory pooling between civilian and military organizations will significantly reduce waste and improve readiness.

TABLE I
POTENTIAL IMPLEMENTATIONS OF AUTOMATIC IDENTIFICATION IN THE DEPARTMENT OF DEFENSE SUPPLY CHAIN.

	Weapons/Machine	Ammunition	HAZMAT	Food MREs	Everyday Supplies	Shipping Port Containers	Personnel
Track/Trace	Auto-ID	Auto-ID	Being Tested	Auto-ID	Auto-ID	Being Tested	Being Tested
Shelf Life/Product Information	Auto-ID	RFID	Being Tested	Being Tested	RFID	RFID	
Inventory Management	Auto-ID	Auto-ID	Auto-ID	Auto-ID	Auto-ID	Auto-ID	
Recall	RFID	RFID	RFID	RFID	RFID	RFID	
Security	RFID	RFID	RFID	RFID	RFID	RFID	RFID
Military/Civilian Interface				Auto-ID	Auto-ID		Auto-ID

D. Predictive Maintenance

The military currently employs a preventive maintenance policy for complex equipment. This means that overhauls occur on a scheduled basis, taking expensive weapons systems out of operation for long periods. This policy is not efficient. With the serialization capability of the EPC, the history of every service part could be stored in a database. The history is a vital piece of information in predicting failure. Rather than scheduling overhauls on a periodic basis, maintenance can take place when a military planner sees that a part is likely to fail. This type of information means that service parts can be pre-ordered and likely to fail component parts, a water pump for example, can be identified and stocked instead of the larger more expensive part systems, an aircraft engine for example. This will enable vehicles to be operated at their maximum efficiency resulting in a reduction of total lifecycle costs.

E. Budgeting

The accurate real-time inventory information provided by the EPC system enables more accurate budgetary decisions to be made. Current budgetary decisions are made based upon faulty information on inventory levels and troop readiness. The EPC system narrows the uncertainty and error in the information being used for budgetary purposes.

F. Summary of Auto-ID possibilities in DoD

Table I provides a summary of specific RFID possibilities. Boxes marked "RFID" suggest that identification tags would improve efficiency in that area. Boxes marked "Auto-ID" indicate that the Networked Physical World EPC system [4] would be substantially more beneficial in those areas than a proprietary RFID system. Those boxes marked "Being Tested" indicate that testing of RFID technology is currently being used or tested.

VI. CONCLUSIONS

Success in warfare increasingly depends on accurate information on the identity and location of parts and systems. This is not only true for battlefield operations but also the support functions responsible for ensuring enough supplies exist at the right location to support the troops. In the future, the United States will face pressure to enhance readiness for war while at the same time minimizing costs of procurement. The Auto-ID Center's EPC system technology will play an important role in this regard by providing open standards for both the military and industry while enabling unprecedented total supply chain visibility.

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