An Analysis of the Department of Defense Supply Chain: Potential Applications of the Auto-ID Center Technology to Improve Effectiveness

by

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Submitted to the Department of Mechanical Engineering in
Partial Fulfillment of the Requirements for the Degree of

Bachelor of Science in Mechanical Engineering
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ABSTRACT

The Department of Defense (DoD) has a very large, complex distribution and supply system. The current systems and processes used to manage these distribution and supply systems are inefficient and often inaccurate regarding the location of items within the systems. These inaccuracies result in the inefficient distribution and supply of items that negatively impacts the cost of DoD operations and, most importantly, the readiness of DoD to perform its duties and execute operations. The Auto-ID Center has developed a Networked Physical World system that enables the accurate, real-time identification and location of all physical items throughout distribution and supply systems. In this thesis, I characterize the DoD distribution and supply systems, identify several significant problems within these systems, and analyze how the Auto-ID Center's system can be used to eliminate these problems and improve the overall DoD distribution and supply systems.

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CHAPTER 1. INTRODUCTION

In this thesis, I analyze the application of the automated identification and management system developed by the Auto-ID Center to the distribution systems and supply chains of the Department of Defense (DoD). This chapter motivates the need for new systems and technologies to be introduced into the DoD distribution and supply chains by identifying some of the existing problems within the DoD's systems. An overview of the DoD's distribution and supply systems is presented, as well as an overview of the Auto-ID Center's Networked Physical World system. Finally, a summary analysis of the use and benefits of the Auto-ID Center's system within the DoD is provided, as well as a summary of this thesis.

1.1 Introduction

The Department of Defense (DoD) has recognized the need for continually improving the management and distribution of its resources. In the recent document, JOINT VISION 2020, which illustrates the military's vision and goals for the year 2020, General Henry Shelton, Chairman of the Joint Chiefs of Staff, stated, "Focused Logistics is the ability to provide ... the right personnel, equipment, and supplies in the right place, at the right time, and in the right quantity, across the full range of military operations" [34]. In order to improve, one must understand the requirements for improvement. First, improvement requires an understanding of the existing systems and processes, their benefits and their limitations. Second, improvement requires a deep understanding of new or different processes and technologies that may be applied, including their benefits and their limitations. Third, improvement requires a view of how a new process or technology can be applied within the existing frameworks, as well as what changes to existing systems and processes may be made to fully leverage the new process or technology. Finally, improvement requires the implementation of the new process or technology in order to realize its benefits.

This thesis work is the first step to improving the DoD's systems with a specific technology, the Networked Physical World system developed by the Auto-ID Center [29]. The first three improvement requirements are addressed in this thesis at an intermediate level of detail. First, the distribution and supply systems used within the DoD are characterized, and the most pressing problems are identified. Second, the Networked Physical World system is evaluated with the capabilities and limitations of its component technologies being identified. Finally, the application of the Networked Physical World system to the DoD distribution and supply systems is analyzed.

The remainder of this chapter provides a summary overview of the findings from this work.

1.2 Introduction to the DoD Distribution System

The DoD has very large, complex distribution and supply systems. Many of these systems span multiple branches of the military. The Defense Logistics Agency (DLA), one of fifteen defense agencies, manages the overall supply chain for the DoD. Additionally, many of DoD chains exist solely within a specific branch of the military.

All DoD distribution channels and supply chains are characterized by long lead times and mobile supply and distribution locations. These characteristics make it difficult to maintain accurate inventories. With a lack of visible information flow, demand becomes unpredictable and variable. With unpredictable demand, DoD supply points are unable to sustain the correct amount of inventory. End users experience variable order-and-ship times (OST), ranging from short if the part is available locally to very long if it must be shipped from a central distribution center. This unreliability leads to several fundamental problems. Delays in shipping hinder the military's ability to operate at a fast-paced, ready-for-war mode. Unreliable inventory leads to overstocking and hoarding to ensure item availability, hampering the mobility of a force with unnecessary surplus in supply.

1.3 Introduction to the Networked Physical World System

The Auto-ID Center has created a Networked Physical World system that is designed to enable the accurate, real-time identification and location of all physical objects. The Networked Physical World system connects physical objects to the Internet by affixing a radio frequency identification (RFID) tag to each object and ubiquitously deploying RFID tag readers to enable all tags to be read, regardless of their respective object's location. The unique identifier stored on a tag identifies the object to which the tag is affixed and acts as a pointer to information about that object that is available over the network.

The ability to accurately and automatically identify all objects in real-time provides instant visibility into any distribution system that implements the Networked Physical World system. This visibility will facilitate inventory management in the Department of Defense. Reorder amounts can be calculated more rapidly and more accurately leading to a lean chain of supply where material is available at the local distribution point. Ability to track individual parts of large machines allows for predictive maintenance where machines no longer need to be removed from military operation for preventive maintenance. Instead, real-time tracking of parts leads to efficient estimations for when a part needs to be replaced. Predictive maintenance allows for efficient use of military resources. A military/civilian interface is possible with implementation of the Auto-ID system where all supplies are characterized by the same language and are stored in a common network. A military/civilian supply partnership can lead to a revolutionary system in readiness for war where civilian suppliers can support military needs.

1.4 Thesis Overview

The remainder of this thesis provides a more detailed view of the DoD distribution and supply systems, the Auto-ID Center's system, and the applicability of the Auto-ID Center's system to the DoD distribution and supply systems. We begin with a summary of the structure of the Department of Defense in Chapter 2. The military is a complicated structure organized by ranks and divisions, comprised of over 1.4 million individuals with an annual budget of about 370 billion dollars. Logistics officers at the battalion level document demand in the military to determine reorder amounts for supply.

Chapter 3 characterizes the specifics of the DoD supply chain. First, a standard consumer packaged goods (CPG) supply chain is outlined. The military supply chain is then described and finally a comparison is made between the two chains. The military supply chain differs from a CPG supply chain in the following ways: 1) diversity in supply, from toilet paper to tanks, 2) the need to be ready for war at any given time, 3) an unstable and therefore unpredictable demand, 4) moving end supply points, and 5) handling of supply orders according to priority. The major goal of a consumer goods supply chain is to minimize cost and maximize profits. The major goal of the military supply chain is readiness for war.

Chapter 4 analyzes the problems within the DoD supply chain. These problems include inventory management where the DoD faces problems such as overstocking and delays in material shipping because supply is not available at a local retail or distribution depot. Repair and maintenance of large equipment is inefficient. Preventive maintenance is practiced, leaving aircraft and other large machinery in the shop for lengthy periods of time. When a spare part is needed, an order is usually slow to arrive delaying repair even further. Finally, readiness and mobility is an issue. The need to improve equipment readiness and military supply is necessary to have a strong and fast fighting power. Supply efficiency is needed in order for soldiers to pack only what they need, thus improving mobility.

The DoD understands the advantages of automatic identification in helping to overcome problems in the supply chain. Numerous tests and grants have been issued to further research in automatic identification in the military. Chapter 5 outlines the existing RFID technology within the structure of DoD. Most implementations are now at the testing stage.

Chapter 6 introduces the Auto-ID Center's Networked Physical World system. The Auto-ID Center is an industry sponsored non-profit organization chartered to design the open standards-based system that connects all physical objects to the global Internet. The five basic structures making up the Center's system include (1) electronic RFID tags and readers, (2) the Savant systems, (3) Electronic Product Code (EPC), (4) Object Name Service (ONS), and (5) Physical Markup Language (PML).

In Chapter 7, I identify areas where the Auto-ID Center's vision fits in the DoD supply chain. The Auto-ID Center's system would improve the efficiency of the military supply chain in the areas of inventory management, tracking of product information, offering a military/civilian common interface, and predictive maintenance for the repair of large-scale items rather than the more time consuming preventive maintenance.

I conclude with Chapter 8 while offering a list of future possibilities in the research of the Auto-ID Center and the Department of Defense.

CHAPTER 2. THE DEPARTMENT OF DEFENSE

This chapter summarizes the structure of the Department of Defense. The military is a complicated structure organized by ranks and divisions, comprised of over 1.4 million individuals with an annual budget of approximately 370 billion dollars. The overall supply chain is managed by the Defense Logistics Agency (DLA), one of fifteen defense agencies. Logistics officers at the battalion level document demand in the military to determine reorder amounts for supply.

2.1 Introduction

The Department of Defense (DoD) is responsible for providing the military forces needed to deter war and protect the security of the United States. The major elements of these forces are the Army, Navy, Air Force, and Coast Guard. The Marine Corps is a subdivision of the Navy. The President serves as Commander-in-Chief and under him the Secretary of Defense exercises authority over the DoD. The remaining elements of the department include the Office of the Secretary of Defense, Joint Chiefs of Staff and the Joint Staff, and the DoD Inspector General. Fifteen Defense Agencies, including the Defense Logistics Agency (DLA), and nine DoD Field Activities operate under the Office of the Secretary of Defense [9]. The DoD operates on a budget of approximately 370 billion dollars.

There were a total number of 1.4 million individuals on active duty in the military as of April 30, 2002 and 1.3 million in reserve. The breakdown in active forces includes 34% Army, 26% Navy, 12% Marine Corps, 25% Air Force, and 3% Coast Guard [10]. The military is organized in a chain of ranks and divisions. The chain of command in the Army is illustrated in Figure 1.

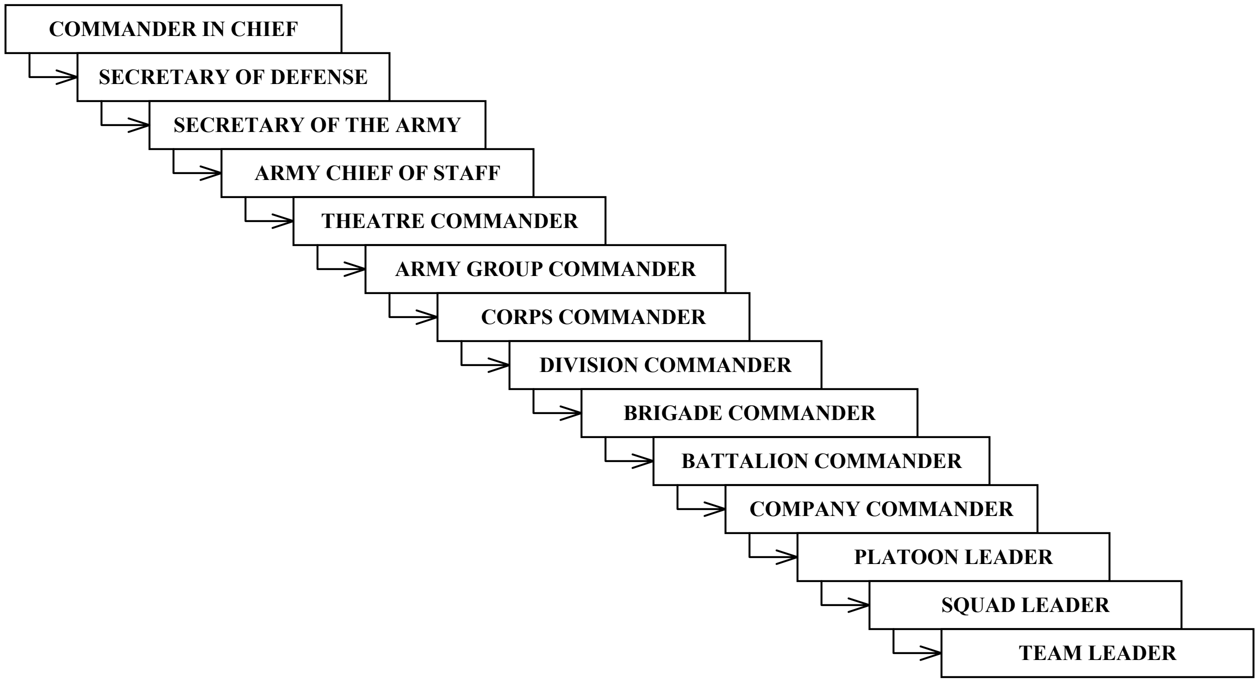

Figure 1: Chain of Command in the Army

Within the Army, there is a structured organization of groups, down to the lowest echelon of 4 or 5 soldiers belonging to a rifle squad [11], as shown in Table 1. The Marine Corps, Navy, and Air Force have similar structures.

DIVISION	NUMBER OF SOLDIERS	COMPRISED OF...	CHARACTERISTICS
Squad	4-10		smallest organization in a tactical unit (i.e. tank crew or rifle squad)
Platoon	16-40	2-3 squads	a group of like squads (i.e. three rifle squads)
Company/Battery/Troop	100-200	3-4 platoons	fight as an integrated unit of a battalion
Battalion/Squadron	500-1,000	4-5 companies	lowest echelon at which firepower, maneuver, intelligence, and support
Brigade	3,000-5,000	2+ battalions	can perform major tactical tasks; primary mission is to deploy on short notice
Division	10,000-15,000	3 brigades	10 total divisions: performs major tactical operations and can conduct sustained battles and engagements
Corps	20,000-45,000	2-5 divisions	four total corps; largest tactical unit
Theatre		all divisions in a theatre	five total theatres: Atlantic Command, Pacific Command, US Army Europe, US Army Korea, US Army South

Table 1: Divisions in the Army

2.2 Logistics and Supply

2.2.1 Supply

The Defense Logistics Agency (DLA) manages supply in the Department of Defense. Headquartered at Fort Belvoir, VA, the main objective of the DLA is to provide logistical services such as logistics information, material management, procurement, warehousing, and distribution of supply to the Army, Navy, Air Force, Marine Corps, and other federal agencies. The DLA was established in 1952 as a result of a recommendation by Herbert Hoover to consolidate logistical activities in the military and now houses approximately 23,000 civilian and military personnel [28].

The DLA manages three main defense supply centers:

1. DSCC in Columbus, Ohio supplies weapon systems spare parts, end items, and construction and electronic spare parts.

2. DSCR in Richmond, Virginia is the main supply for aviation weapon systems and also supplies repair parts and operating items.

3. DSCP in Philadelphia, Pennsylvania supplies food, clothing, textiles, medicines, medical equipment, general and industrial supplies.

Supplies are stored in distribution centers until deployment to military units. There are two primary distribution sites (PDS), one in Susquehanna, PA and the other in San Joaquin, CA. These depots supply to twenty-two local defense distribution centers (DDC) around the nation [28].

2.2.2 Demand

Demand of goods is managed at two levels. A company will include a support platoon in charge of LOGPAC (logistics package) operations. LOGPAC is a grouping of supplies sent to companies for re-supply. The HHC (Headquarters and Headquarters Company) Commander organizes and supervises the LOGPAC operations of the support platoon. Above the HHC Commander is the battalion S4, supply officer, who is the main officer in charge of managing internal supply. The Battalion S4 monitors requisition, temporary storage, distribution of supplies, and unit basic loads and advises the commanders according to his findings.

CHAPTER 3. SUPPLY CHAINS

The Department of Defense has a supply chain worth characterizing. We begin by examining a standard consumer packaged goods (CPG) supply chain. The military supply chain is then described, and a comparison is made between the two chains. The military supply chain is much more involved than a CPG supply chain for the following reasons: diversity in supply, from toilet paper to tanks, the need to be ready for war at all times, an unstable demand, moving intermediate and end supply points, and handling of supply orders according to priority. The major goal of a consumer goods supply chain is to minimize cost and maximize profits. The major goal of the military supply chain is readiness for war.

3.1 A Consumer Packaged Goods Supply Chain

A standard consumer packaged goods (CPG) supply chain is straightforward as shown in the Figure 2.

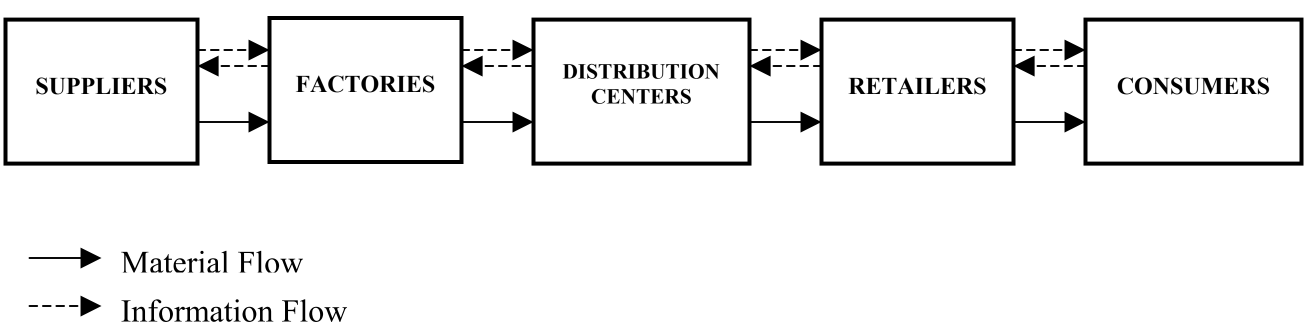

Figure 2: Consumer Packaged Goods (CPG) Supply Chain

Suppliers supply material to factories that manufacture the products. Products are stored at distribution centers, ready for transport to retailers. Consumers purchase products from retailers. Retailers base their order amounts on demand from consumers. Demand from retailers determines distribution center order amounts, which in turn show factories how much they need to produce.

Standard information flow travels only between two units of direct material flow. Consumers communicate their needs to retailers; retailers in turn order more or less from distribution centers, etc.

3.2 Department of Defense Supply Chain

Military demand is complicated in terms of range of supplies, movement of supplies, and reserving supplies for war. Military resources consist of a complicated web of supplies ranging from clothing to nuclear weapons. The DoD organizes all military supplies into ten classes as shown in Table 2.

CLASS	DESCRIPTION
I	Subsistence and commercially bottled water.
II	Clothing, individual equipment, tools, tool kits, tents, administrative and housekeeping type supplies, as well as unclassified maps.
III	Petroleums, oils, and lubricants: includes bulk fuels and packaged products such as antifreeze.
IV	Construction items, including fortification and barrier material.
V	Ammunition.
VI	Personal demand items (nonmilitary sales items) and gratuitous health and comfort pack items.
VII	Major end items, such as launchers, tanks, mobile maintenance shops, and vehicles.
VIII	Medical supplies, including repair parts for medical equipment.
IX	Repair parts and components required for maintenance support of all equipment.
X	Material to support nonmilitary programs, such as agricultural and economic development.

Table 2: Classes of Supply in the Military [8]

Military inventory management must take into account the possibility of war at any moment. Thus, there is a necessity to store resources used on a daily basis as well as store resources for times of war. The military distinguishes these groups as loads. There are three types of loads: operational, basic, and prescribed. Operational loads are the quantities of Class I through V and VII supplies that a unit needs to operate during peacetime. Basic loads, determined by MACOM (Major Army Command), are quantities of Class I through V and VIII supplies which allows a unit to initiate combat. These items are used during peacetime only if operational loads run out. As basic loads expire, they are replaced and cycled through operational load. Prescribed loads are maintenance specific quantities of Class II, IV, VIII, and IX needed to support a unit's maintenance program [8].

At peacetime, military supply movement is fairly straightforward, as outlined by Figure 3. In the continental United States (CONUS), the supply chain mimics a consumer goods supply chain. There are two primary distribution sites (PDS), one in Susquehanna, PA and the other in San Joaquin, CA. These depots supply to twenty-two local defense distribution centers (DDC) around the nation. Supply points request supplies from their local retail, supply support activity (SSA), and when available, items are directly shipped to the supply points. Otherwise, a material release order (MRO) is issued to the local DDC and the DDC sends a request to the National Inventory Control Point (NICP). The NICP queries the primary distribution sites. When supplies are available, they are shipped from PDS to DDC, from DDC to local SSA, and finally to the supply point [30].

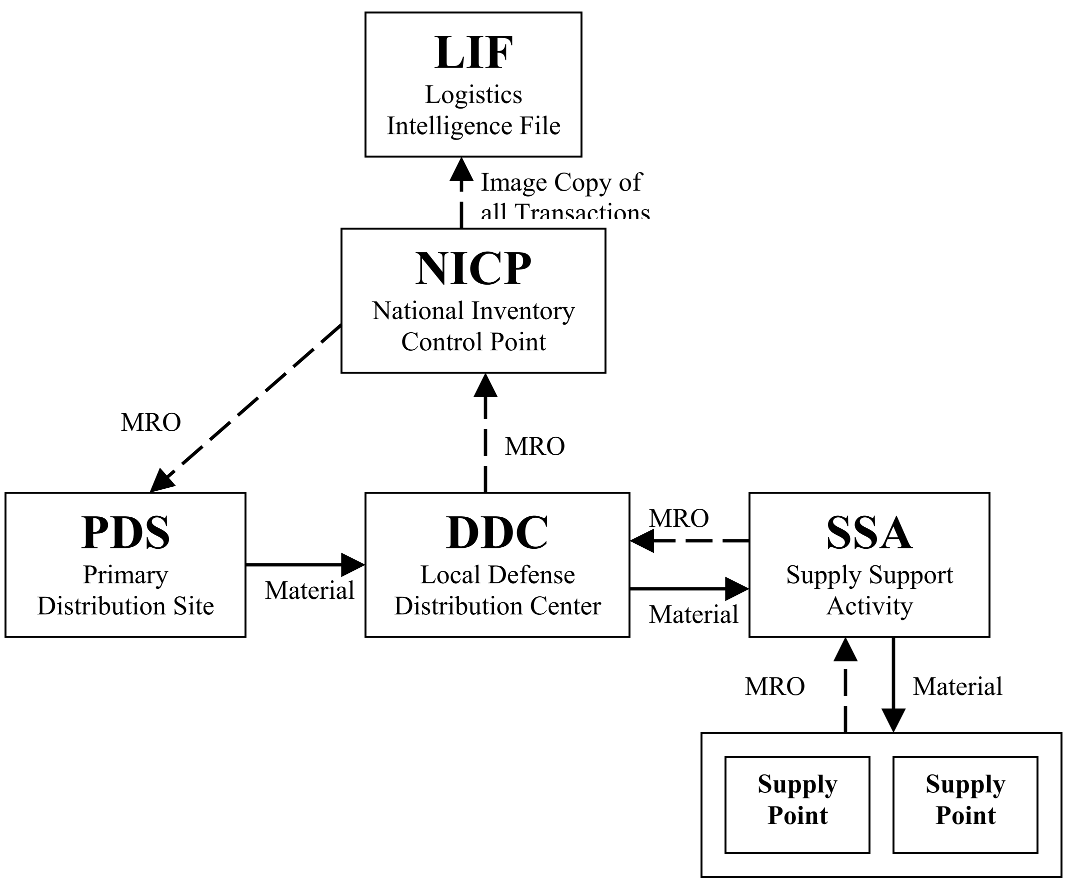

Figure 3: Department of Defense CONUS Supply Chain

In theatre, the peacetime supply chain is slightly more complicated as shown in Figure 4. There are three levels of management: the theatre level which manages an entire theatre area, the corps level which manages a specific branch of armed forces, and the division level which manages a small localized area within a theatre. Within a theatre there are numerous supply points. Supply points are assigned to a direct support unit (DSU) and a general supply unit (GSU). Each DSU supplies to approximately 3-5,000 troops while a GSU supplies to approximately 65,000 troops. A DSU is equivalent to a local retail store whereas a GSU functions much like a warehouse [8].

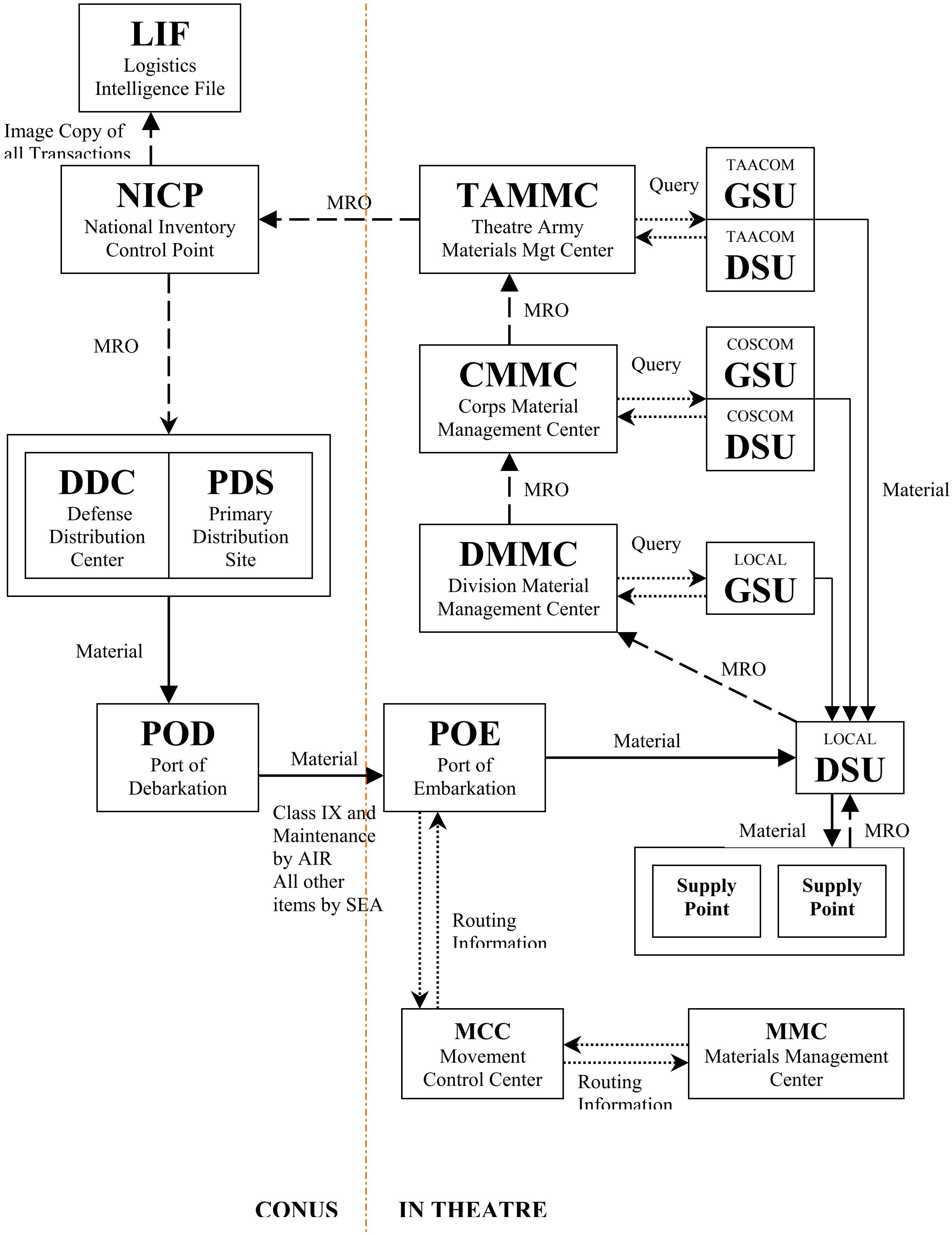

Figure 4: Department of Defense IN THEATRE Supply Chain

Supply points submit material requests to their direct supply unit and when possible, supplies are given directly from the local DSU. In the case where the DSU does not have the supply, an MRO is sent to the Division Material Management Center (DMMC). The DMMC edits the request for validity and priority. Then in order of priority, the DMMC queries the local GSU. If the GSU has the item, it is sent to the supply point. If the DMMC finds that the local GSU does not have the item, and an MRO is sent to Corps Material Management Center (CMMC). The CMMC edits the request for validity and priority. Then in order of priority, the CMMC queries all the GSU and DSU within the corps to find the item. If the item is found, it is shipped to the supply point. If the CMMC finds that the Corps level GSUs and DSUs all do not have the item, an MRO is sent to the Theatre Army Material Management Center (TAMMC), where again the MRO is edited for validity and priority. The TAMMC then queries all the GSU and DSU within the theatre area to find the item. If the item is found, it is shipped to the supply point. If the item is not found, the TAMMC submits an MRO to the National Inventory Control Point (NICP) at CONUS. NICP then queries the PDS. Once the item is found, it is sent to the closest US Port. Class IX items and any other items related to maintenance are shipped by AIR and all other items are shipped by sea. At the theatre port, the item is held while the Movement Control Center (MCC) is contacted to advise of best routing plan. The MCC collaborates with all MMC to find the most efficient route movement. Item is then shipped to the supply point. All transactions through the NICP are copied and sent to the Logistics Intelligence File (LIF) for archival of information [8].

During transition to war, this stable supply chain is abandoned for wartime supply mode. The first mode of action is the Supply Support Activity (SSA) initiates selective cancellation on requisitions that are nonessential for combat and unnecessary for individual health and welfare. Combat forces, supply points, must initially rely on basic loads, oversea war reserves, and air delivery of Class IX and other maintenance related items. Basic loads are kept in reserves at the DSU and GSU level in case of war. Companies rely on operational loads on a normal basis and leave the basic loads for wartime. DSUs usually stock a basic load of about 30 days while a GSU will stock for 5-10 days. Oversea war reserves and supplies pre-positioned on merchant ships will also supply to the corps and theatre level GSUs once hostilities begin. These reserves are used only in times of war; otherwise they remain positioned near a theatre for quick response. There are also pre-positioned materials configured to unit sets (POMCUS) that are held at the depot level at CONUS. Once war begins, a unit directs the NICP to release these POMCUS items to supply points [8].

3.3 Military Supply versus Consumer Supply

On a basic level, the military supply chain mimics a consumer goods supply chain. There are manufacturers to make the products, warehouses to store the products, retail stores (general supply units), and local stores (direct supply units). However there are important differences that DoD has to consider.

First, the military's inventory consists of a large number of very different types of items, from everyday supplies of food and clothing to specialized military equipment, thus creating the necessity of classes of supplies as illustrated in the previous section. The material classes may differ in supply strategies employed such as inventory levels, push versus pull systems, and transportation/packaging techniques.

Second, the military must operate at peacetime yet still be ready for war at any given moment. Equipment and supply readiness is crucial. The metric for military supply chain success is readiness for war, not profit gain. The practice of loading is used to create this phenomenon.

On CONUS, distribution centers must also be ready for wartime demand. With all the basic loads, reserve items, and DDC and PDS storage, there is a complex arrangement of inventory to manage. In one example the shelf life for Class I MRE's is three years. Since the military wants to be prepared at all times in case of war, a large supply of MREs must be sustained at the warehouse level. As a result, most MRE's will sit in a warehouse for close to three years before they are shipped out for consumption, thus creating a three-year supply of MREs at the warehouse level. The MREs that soldiers are eating on the field are usually close to the end of their shelf life [7].

Third, the military supply chain is unstable compared to a relatively stable consumer supply chain. Within a time frame of months, a consumer's demand for a product will hardly change as compared to a military's demand for supplies. Military demand is often variable and unpredictable [2]. Conflict can arise anywhere at anytime. With conflict, more supplies are needed. Immediate Class I and II items, including clothing and other basic items, need to be available to soldiers. In a large-scale war outbreak, Class VII items, major-end items such as tanks, need to be immediately available for effective military operation. Finally new and more complicated technology and a move towards the digital world have caused demand for repair parts to be less predictable.

Fourth, the end points of the supply chain in theatre are moving points, creating another complication in transportation of supply. In a CPG supply chain, products are shipped to a fixed network of retail stores. Consumers make the trip to retail stores to purchase their items. In theatre, military units are moving around constantly, thus the need for the many divisions of material management centers and movement control centers.

Fifth, supply is handled according to priority. At every requisition stop point, priority is assigned to a product need according to UMNIPS (Uniform Material Movement and Issue Priority System). Priority is designated by consideration of UND (urgency of need) as determined by a unit commander [20]. Priority creates one more complication that a CPG supply chain need not consider.

CHAPTER 4. CURRENT PROBLEMS IN THE DEPARTMENT OF DEFENSE SUPPLY CHAIN

With such a large and complicated supply structure, there are bound to be problems and inefficiencies. Some of the major problems include inventory management where the DoD faces problems such as overstocking and delays in material shipping because supply is not available at a local retail or distribution depot. Repair and maintenance of large equipment is inefficient. Preventive maintenance is practiced leaving aircraft and other large machinery in the shop for lengthy periods of time. When a spare part is needed, an order is usually slow to come delaying repair even further. Finally, readiness and mobility is always an issue. The need to improve readiness in equipment and military supply is necessary to have a strong and fast fighting power. Supply efficiency is needed in order for soldiers to pack only what they need, thus improving mobility.

4.1 Inventory Management

The previous logistics attitude of the military was to overstock everything, a "just in case" approach. This overstocking method came about for a number of reasons. Reorder formulas to determine reorder amounts have been developed and used throughout the years. One study found that workers often did not understand the formulas and relied on past experience to determine reorder amounts [12]. Improper record keeping of products received and ordered also proved to be a problem [12]. The most significant reason for overstocking however is the unreliability of order-and-ship time (OST). The tail-end of distribution (last 1% of distribution which takes over 119 days) drives behavior of hoarding or multiple ordering in hopes that one of the orders will come quickly [1]. With a decreasing budget and more expensive technology, the military can no longer afford to merely overstock.

The longest process delays appear in the initial segment (order) and the final segment (transit, crossdock, and receipt processing). Delays in ordering are due to financial holds and manager reviews of individual requisitions. Delays in transit, crossdock, and receipt are due to mixing of shipping modes Small (FedEX), Large (UPS), LTL, TL. [1]

Delays also occur because managing what to stock, reorder points (ROP), and turn-over rates is very difficult due to the unpredictability and variability in demand and the use of highly varied products, from specialized, expensive, slow-to-order military equipment to common, fast, cheap civilian goods. A military customer usually gets 25% of supplies from local retail, 10% from neighboring retail, and 55% from wholesale. On the international scale, DLA-West fills only 54% of Korea's requisitions while DLA-East fills 21% [1]. This procedure is extremely inefficient.

4.2 Repair and Maintenance

Repair of large equipment is inefficient. Spare parts are often not available immediately in the shop. It is difficult to predict what to stock because it is unclear what part will break and when. It would be far too expensive to stock everything especially because there is no active log of subparts in complicated machines. Machinery will sit unused while spare parts are ordered and often backordered because of above mentioned inventory problems. Another common problem is that more expensive items are given high priority and usually come fairly quickly. But it is often the cheaper items that take too long and are necessary to make the actual repair [5].

To prevent lengthy repairs, the military schedules preventive maintenance. These activities, however, prove to be inefficient in many ways. A maintenance manager is in charge of creating a maintenance schedule. The schedule will do its best to account for constraints in machinery use. For example, with aircraft, the following constraints apply.

1. certain types of aircraft not allowed to load/unload at certain airfields
2. certain aircraft not allowed to refuel at certain airfields
3. aircraft not allowed to land/take off at airfields during sterile periods (specific part of day)
4. certain cargo items cannot be mixed with others (HAZMAT)
5. some airfields do not allow simultaneous loading ad refueling of an aircraft
6. some airfields do not allow crew changes
7. limited total number of throughput through an airfield in one day
8. max landing and takeoff weights different for different aircraft at different airfields
9. aircraft must return to home base for scheduled maintenances
10. only C-5 aircraft can carry outsized cargo

With limited aircraft supply, frequent maintenance becomes a problem in military efficiency. In some cases, military officials will overrule the scheduled maintenance causing more disruption in the caring of the machinery [22]. Submarines have even lengthier maintenance schedules.

> 16 months service → 2 months maintenance → 16 months service → 4 months maintenance →16 months service → 2 months maintenance → 16 months service → 2 year major refit

Maintenance schedules leave officials feeling at a shortage of resources. Submarine officials may decide to purchase additional boats when this shortage occurs. By the time a submarine is manufactured, there is no assurance it will still be needed [25].

4.3 Readiness and Mobility

The best metric in determining efficiency of military supply chain is to observe their readiness and mobility. Stockpiling large amounts of inventory in theatre greatly handicaps mobility [20]. A better method in determining supply needs is necessary.

Readiness also relies on air force mobility. Military Airlift Command (MAC) manages airlift resources in times of necessary fast movement, often during the first month of conflict. MAC organizes the transport of aircraft, crews, ground support, and other personnel and equipment [13]. Reliable aircraft availability and rapid visibility of transport items is necessary to deploy as fast as possible.

CHAPTER 5. EXISTING RFID TECHNOLOGY IN DOD

Radio frequency identification (RFID) technology is a growing strategy for improving supply chain efficiency in the Department of Defense. The Department of Defense has invested millions of dollars in the research and development of RFID systems to improve security, cargo visibility, inventory management, product tracking, and quality control. Some of the large-scale systems being implemented include Total Asset Visibility, Smart and Secure Tradelines, and SmartWatch.

5.1 Security

Automatic Vehicle Identification (AVI) is a project with the objective of enhancing security and efficiency at access control points. The US Army hired Transcore Incorporated to test access control at Fort Monmouth, NJ using passive UHF (ultra high frequency) eGo RFID tags. Transcore Incorporated provides technology-based services and products that enable its customers to efficiently manage ground transportation systems, assets and transactions.

Testing began in November 2002. Vehicles with clearance were equipped with eGo tags on their windshields. As cars approach the research center, they pull up to 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 driver is identified using old procedures.

Technology used includes the eGo windshield sticker tag and the eGo 2210 reader. The sticker tag is paper-thin, RF-programmable, passive (battery-free) tag that operates in the 915 MHz range. The tag is tamper resistant, can withstand extreme temperatures, sunlight, humidity, and vibration. Approximate cost of tag is $10. The reader (39.4 x 39.4 cm) can read conventional ETC transponders, eGo tags, ATA-compliant and ISO-compliant RFID tags. The reader identifies tags with a 64-bit tag ID or 1024 bit memory.

Testing is still in progress.

5.2 Cargo Asset Visibility and Security

DoD is working closely with Savi Technology in Smart and Secure Tradelines (SST) and Total Asset Visibility (TAV). The objective of this project is two fold. Smart and Secure Tradelines aims to put tags on containers in Japan before they are shipped to the United States in an effort to provide information about the container's journey when it arrives at a port. The tag would know when the container was opened and closed and who packed the container. The tag would also have information about what should be inside the container. A weight check could verify this information. Currently, less than 2% of containers arriving at US ports are opened and inspected. Most containers are not opened until they arrive at their final destination. One can imagine how horrible it would be to have a bomb be shipped in by a terrorist just to pass port inspections and travel to its destination site without question.

Total Asset Visibility was created by Savi as an initiative to track cargo containers in an attempt to have knowledge of where any cargo is at any given time. Testing is occurring at Hutchison-Whampoa, PSA Corp and P&O Ports. The system is based on Savi's Universal Data Appliance Protocol (UDAP), which allows for integration of devices such as RFID and GPS.

5.3 HAZMAT Recognition

The DLA organized a complete test of Advanced HAZMAT Rapid Identification, Sorting, and Tracking (AHRIST). The objective was to track HAZMAT through the supply chain to quickly identify arrival and departure of HAZMAT using Microchip Logistics technologies. The goal is to reduce DLA liability. At present there is no system that consistently alerts personnel or Automated Information System (AIS) of arrival of HAZMAT.

The DLA HAZMAT Supply Chain consists of 44,000 vendors and 300,000 customer locations. DLA or a Service purchases HAZMAT through the Inventory Control Point (ICP). ICP then negotiates a contract with a vendor. A material safety data sheet (MSDS) is sent to DLA to be incorporated in DOD Hazardous Material Information System. Finally, HAZMAT is shipped to a distribution center. Richmond, VA is the primary HAMAT distribution center. HAZMAT may move from the Primary Distribution Site to local distribution centers to customers or may move amongst the distribution sites. Returns of HAZMAT are regulated by the customer. The customer pays charges of return and bears responsibility of packaging HAZMAT according to guidelines. Used and returned HAZMAT are sent to the Defense Reutilization and Marketing Service to be recycled or disposed.

Operating frequencies used in testing included 862-870 MHz in Europe, Africa, and USSR, 902-928 MHz in North and South America, and 2.45 GHz in the Pacific and Asia. Tags had a read range of 10 feet and stored 128 8-bit bytes. Interface software was provided by Gateway.

Tests included environmental tests, ruggedness tests, technology and process validation tests, and real world tests. Environmental tests evaluated performance of tags under varying environmental conditions (temperature, humidity), electromagnetic interference, and validate frequency of emissions. Testing was done in Oak Ridge National Laboratory. Ruggedness tests evaluated performance of tags after exposure to static weight, vibration, and shock. Testing was done in National Transportation Research Center in Knoxville, TN. Technology and validation tests measured the readers' ability to track individual items, containers of individual items and pallets of multiple containers carrying individual items. Testing was done in Mechanicsburg site at Susquehanna, PA. Real world tests measured performance and limitations of technology in a real world setting. Testing was done in Mechanicsburg, PA.

The metric of testing was percentage of tags read. Most tests resulted poorly (between 40-50% read rate. Lowest results occurred in moving tests and real world tests. Humidity and temperature tests were not a problem. Performance of tags was heavily affected by what material the tag was mounted on. The appropriate tag must be matched to the appropriate material for satisfactory performance. Researchers also concluded that a lack of a worldwide RFID standard was hindering the acceptance of use [4].

5.4 Tracking and Product Information

DoD is also working closely with Symbol Technologies, Zebra Technologies, and Texas Instruments in material tracking applications. In 1999, Symbol was awarded a 5-year contract for up to $248 million for automatic identification technologies and services. Projects include deployment of materials and personnel throughout the world, tracking supplies through global distribution centers and logistics network, 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. Computer interface includes use of the IBM ES9000 Series mainframe running Mincom's Management information System (MIMS). The project will track goods receiving, spot-checking, and special care during distribution such as batch number, shelf life, expiration date, and repairable or non-repairable categories.

5.5 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 case-level, pallet level, and container level. Currently, identification tags are only placed at the container level. The primary application of these tags is to have the ability to automatically update inventory. There is no quick and automatic method in deciding reorder amounts at supply points. As a result, commanders often order too much as a safety measure. With new technology in the advancing military, it is necessary for soldiers to have a lighter load. Adding unneeded food supply slows down the force. Also, any surplus food goes to waste.

RFID tags also track product information. An MRE shelf life is approximately three years. Since there is a need to be ready for war at any given time, MREs are stored at the warehouse level until close to the end of its shelf life. Then it is shipped to supply points to be consumed by military personnel. Since MREs are being consumed at the end of their life cycle, it is important to know the environmental conditions of the MRE during its lifetime (i.e. temperature, humidity). Possible advantage of RFID tags is the prospect of a dynamic shelf life. The shelf life of an MRE is dependent upon the environmental conditions in which the MRE is exposed during its lifetime [6].

CHAPTER 6. THE AUTO-ID CENTER

The Auto-ID Center is an industry sponsored non-profit organization chartered to design the open standards-based system that connects all physical objects to the global Internet. This system is referred to as the Networked Physical World system. The five basic structures making up the Auto-ID Center 's system include (1) RFID tags and readers, (2) the Savant systems, (3) Electronic Product Code (EPC), (4) Object Name Service (ONS), and (5) Physical Markup Language (PML).

6.1 RFID Tags

Electronic tags are the wireless connection between the physical and virtual world. Each tag consists of a small microchip that holds a unique identifier, an antenna that communicates with a reader, and an optional battery. Tags with batteries are "active" and have higher costs than a "passive" tag, with no battery, which harvests its energy from the reader to power the tag and communicate information. In addition to tags, the Auto-ID Center has developed a means to uniquely identify objects and a method of storing and retrieving data [33].

6.2 Electronic Product Code

The Electronic Product Code (EPC) is a globally unique identification scheme designed to uniquely identify all physical objects and aggregations of objects. The EPC code is sufficiently large to enumerate all objects. The EPC is intended, as much as possible, to be universally and globally accepted. Since the EPC is used primarily to link physical objects to the network, it was designed to serve as an efficient information reference. Finally, the code is extensible, allowing future expansion in both size and design.

The EPC representation consists of four distinct, hierarchical partitions: version number, domain manager number, class code, and serial number. All EPC codings contain these four partitions. The first partition, the version number, contains information on the length and structure of the code being used, and the three remaining partitions contain the actual unique identifier for the object [33].

6.3 Object Name Service

The Object Name Service (ONS) links the Electronic Product Code with its associated Physical Markup Language (PML) data file(s). The ONS is a system designed to automatically locate networked information and services for tagged objects. More specifically, the ONS is an automated networking service, which, when given an EPC number, returns a set of host addresses on which the corresponding PML files or services are located.

The ONS is based on the standard Domain Name Service (DNS). Within the ONS System, the EPC is translated into a valid DNS domain name. This domain name is used to obtain the set of IP addresses in the standard DNS manner. Unlike DNS, the ONS has multiple roots corresponding to a public and multiple private ONS hierarchies. The private ONS hierarchies are required to locate local information and services stored for a particular EPC [33].

6.4 Savant Systems

A Savant system is an event router and local control system that performs operations such as data capture, data monitoring and filtering, and data transmission. Networked Savant systems form a framework to manage and react to the EPC values communicated to the tag readers. The Savant systems are deployed in a hierarchical, distributed framework. This topology enables the Savant framework to handle large volumes of communicated EPCs from networked objects [33].

6.5 Physical Markup Language

The Physical Markup Language (PML) is a language for describing physical objects. The PML is based on the eXtensible Markup Language (XML) and includes a set of schema describing common aspects of physical objects. The Physical Markup Language (PML) is intended to be a general, standard means for describing physical objects with particular emphasis on practical applications, such as inventory tracking, automatic transaction, supply chain management, machine control and object-to-object communication [33].

CHAPTER 7. HOW AUTO-ID AND DOD COME TOGETHER

The DoD has been testing RFID technology for a number of years but the key element that they are missing in their implementation is the advantage of standardization. Everything in the world will be uniquely identified under the same standard system in the Auto-ID Center's vision. With a standard system, DoD can become a more integrated system within itself and in conjunction with the civilian world.

7.1 Inventory Management Across the Board

It is already apparent that the Department of Defense is the largest organization in the world, comprised of 1.4 million active members, an annual budget of 370 billion dollars, and an intricate network of supplies that range from toilet paper to B-52 bombers. A standard system of automatic identification across the entire DoD will facilitate inventory management; thereby creating increased readiness at a reduced cost.

As discussed in Chapter 4, a major issue in inventory management is reorder amount. The Auto-ID system provides a method of real-time automatic inventory tracking. In the case of reordering MREs for a battalion, a commander need only read the number of available MREs off a computer screen to know how much should be reordered. In a more advanced military, the reorder is performed automatically.

Distribution of goods can become more efficient when there is a single database of inventory movement. A military customer usually obtains 25% of supplies from local retail, 10% from neighboring retail, and 55% from wholesale as discussed in Chapter 4. With a standardized system, the DLA has more visibility of reorder patterns (customer demand) and inventory movement amongst distribution centers and between distribution centers and supply points. Efficiency in supply will improve.

RFID technology coupled with mass serialization and the ONS database allows for real-time tracking of supplies from a single source. In the case of maintenance and spare parts, a standardized system of inventory management will give visibility to where spare parts are located. Maintenance and repair becomes more efficient.

7.2 Product Information

The Auto-ID Center's system expands the capabilities of product information in product history and product lifetime conditions. The EPC read by a reader is merely a unique identifier pointing to a database holding all information about an item. A current UPC holds information regarding manufacturer and product. With the Auto-ID Center's system, any person along the supply chain can find out all details about a product, including suppliers of every piece of the product, transportation methods, and environmental conditions around the product throughout its lifetime. There is also the possibility of a dynamic shelf life where shelf life varies with the conditions that the product has been exposed to. Customers will, in general, have more information about a product, allowing them to make better decisions about the use of the product.

7.3 Military and Civilian Interface

With a standardized system, the DoD can be integrated with the civilian world. Supply of Class II items would be handled much more efficiently if product information could easily transfer between the civilian contractors and the DoD. For example, if the DoD chooses to include commercially made protein bars in meal packages, they would be able to purchase from a CPG point of supply and seamlessly be able to access product information under their same system. There would be no need to attach a new identification tag or to enter any data into the DoD's system.

An active military/civilian interface also reveals the opportunity for collaboration between CPG and military in readiness for war. CPG warehouses can assist the military in stockpiling for the in-case-of-war scenario. They could potentially carry an inventory that would never fall below a set amount. The DoD would determine that set amount in accordance with what they need in times of war. The CPG warehouse can recycle that stockpile with products to be sold. Waste would be drastically diminished since products will not be left to expire. The military would also need to stock less supplies with the cooperation of CPG suppliers.

7.4 Predictive Maintenance

Maintenance and repair of large-scale products, Class VII, require constant maintenance and repair. The current philosophy in equipment maintenance is preventive maintenance, meaning that regular maintenance checks are performed to try to catch damages before they occur. For example, in terms of aircraft, all aircraft are scheduled for preventive maintenance checks after x number of hours of airtime. This method is not efficient. Implementation of the Auto-ID

Center's system will lead to improvement. With Auto-ID Center technologies, every part and the history of a large-scale machine can be stored in a database. Failure of any part can be predicted based on the history of that part in other machinery. When a commander sees that a part in a machine is likely to fail in the near future, he can 1) order the part ahead of time and 2) perform maintenance on the machine before the time of predicted failure. This method will enable aircraft to be operated at their maximum efficiency. They will only be maintained when absolutely necessary and spare parts will be ordered ahead of time, thus lowering wait time while the machine is being repaired.

7.5 Summary of RFID possibilities in DoD

Table 3 provides a summary of specific RFID possibilities discussed in Chapters 5 and 7. Boxes marked "RFID" suggests that identification tags would improve efficiency in that area. Boxes marked "Auto-ID" suggests that the Networked Physical World system would be substantially more beneficial in those areas than any proprietary RFID system. Those boxes marked "Being Tested" suggests that testing of RFID technology is currently being used or tested.

	Weapons/ Machine	Ammu-nition	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		

Table 3: Potential Implementations of Automatic Identification in the Department of Defense Supply Chain

CHAPTER 8. CONCLUSIONS

The objective of an effective military supply chain is readiness for war. This goal forms the basis for the complexity of the DoD supply chain. Compared to a standard consumer goods supply chain, the military supply chain has additional requirements and considerations: diversity in supply, from toilet paper to tanks, equipment readiness for war, an unstable and unpredictable demand, moving end supply points, and handling of supply orders according to priority. These considerations give rise to problems and complications such as difficult inventory management, inefficiencies in equipment maintenance and repair, and oversupply and long ship times leading to decreased mobility and readiness of a force.

DoD has already recognized the potentials of automatic identification through radio frequency technology. Testing already in progress includes cargo asset visibility and security, HAZMAT recognition, tracking product history and lifetime environmental conditions, and MRE quality control. To further the DoD's progress in automatic identification, the Auto-ID Center's vision is crucial. The Auto-ID Center is an industry sponsored non-profit organization chartered to design the open standards-based system that connects all physical objects to the global Internet. Through the standardized and ubiquitous Auto-ID system, the military will perform with highest efficiency. The Auto-ID Center's system will enable lean and efficient inventory management, real-time and dynamic tracking of product information, open the gateway to a military and civilian supply partnership with its standard interface, and make possible predictive maintenance for the repair of large-scale items rather than the more time consuming preventive maintenance.

Although the Auto-ID Center's system is an advantageous move for the Department of Defense, there are still issues to be addressed further. First, the military is a large, slow-to-change system. Technology reaches the organization quickly but permeates slowly (requisitions are still performed using signatures and physical paper). It is possible that the entire organization is not technologically advanced enough to incorporate RFID technology into their systems.

There is an issue of privacy and security that the military must uphold. In the areas of food and everyday supplies, the issue at hand is not as great. However, when it comes to weaponry, it is not sensible to have tags that can be universally read by readers all over the world. It is a necessary component, though, in order to uphold the "ubiquity" vision of the MIT Auto-ID Center. There, less promiscuous secure tags must be used on some items.

There are process problems still to be solved in the use of the Auto-ID Center's system. An EPC may be used to uniquely identify and item such as an engine. The engine is an aggregation of parts that may change over time. The processes for how to maintain the current and past part compositions for the engine must be designed and implemented.

In the areas of ordnance, HAZMAT, and food, items will see a good deal of handling abuse. Tags could easily be damaged in transit. Therefore, ruggedized tags may need to be utilized on some items.

In the area of ordnance, most materials are made of metal. RFID tags on metal surfaces have proven not to be the most effective combination. As shown in the AHRIST testing discussing in

Chapter 5, it is necessary to use the appropriate tag on an appropriate material to create optimal reading results.

As with any new technology, there will be bugs on the onset. But despite the bugs, the Auto-ID vision is a necessary element in improving the efficiency of the Department of Defense supply chain.

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