



What Warehouse Automation Best Practices
Should USSOCOM Consider Using?

Manfred L. Little II

Defense Acquisition University
Senior Service College Fellowship 2016-2017
Huntsville, Alabama

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Author: Manfred L. Little II

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Abstract

Automation is changing supply chain operations across the world. Businesses are looking for ways to maximize throughput, while increasing the accuracy of orders by taking advantage of automated materials handling (MH) equipment, advanced conveyor systems, and robotic applications (Fiveash, 2016).

This research paper explores the many different warehouse automation tools used by industry, a modern Army Supply Support Activity, as well as automation tools currently used and explored by the Defense Logistics Agency (DLA). Although, the United States Special Operations Command (USSOCOM) has service like responsibilities, as a command it is much smaller than the Services (Army, Navy, Air Force, and Marine Corps) and has a much smaller supply chain operations requirement. However, USSOCOM's supply chain operations, specifically warehouse operations, could benefit by better understanding some of the best automation practices used by industry, the Army, and DLA. This paper will explore various warehouse automation practices that if implemented, could make USSOCOM warehouse operations more efficient, improve inventory accuracy, and provide better asset visibility.

Introduction

Background

Imagine a self-guided forklift quickly traversing through a high-bay narrow aisle of a modern warehouse, automatically pushing inventory into a rack system high above the warehouse floor, as auto-guided robots move outbound inventory to fulfillment stations lit up like a Christmas tree, processing orders up to 2,400 picks per hour. As orders are completed, a sophisticated conveyor system transports packages to a stationary robot, which loads the packages into a driverless transport vehicle. Is this a warehouse of the future? No, it is the modern warehouse of today (Fiveash, 2016)!

Automation is changing supply chain operations across the world. Companies throughout the world, are looking for ways to maximize throughput, while increasing the accuracy of orders by taking advantage of automated materials handling (MH) equipment, advanced conveyor systems, and robotic applications (Fiveash, 2016).

This research paper analyzes automation tools used by industry, an Army Supply Support Activity (SSA), and Defense Logistics Agency (DLA). Although the United States Special Operations Command (USSOCOM) has service like responsibilities, it is much smaller in manpower, budget, and scope than the Services (Army, Navy, Air Force, and Marine Corps) and has a much smaller supply chain operations requirement. However, USSOCOM's supply chain operations, specifically warehouse operations, could benefit by better understanding the best automation practices used by industry, the Army, and DLA. This paper will analyze various warehouse automation practices that could improve the efficiency, accuracy, and asset visibility of USSOCOM warehouse operations.

United States Special Operations Command (USSOCOM)

Following the failed Iran hostage rescue mission (Operation Eagle Claw), the 1987 Defense Authorization Act (the Cohen-Nunn Amendment to Goldwater -Nichols Act) elevated Special Operations Forces (SOF) to the unified command level by creating USSOCOM. USSOCOM was the first Unified Command that directed the joint efforts of SOF units from each service (Holzworth, 1997).

USSOCOM was formally established as a unified combatant command at MacDill Air Force Base, Florida on 16 April 1987, and commanded by a four star general officer with the title of Commander in Chief, United States Special Operations Command (10 U.S.C. § 167). According to Title 10 of US Code, the commander shall be responsible for and have the authority to develop and acquire special operations-peculiar equipment, material, supplies, and services.

To carry out the acquisition duties specified, the command is authorized a Special Operations Acquisition Executive (SOAE). The command acquisition executive is responsible to the commander for rapidly delivering acquisition solutions to meet validated special operations-peculiar requirements and is subordinate to the Defense Acquisition Executive in matters of acquisition (10 U.S.C. § 167).

The name of the acquisition organization within USSOCOM responsible for acquisition and logistics of Special Operations Forces (SOF) is SOF Acquisition, Technology, and Logistics (SOF AT&L). Its mission is to provide rapid and focused acquisition, technology, and logistics to Special Operations Forces (Joint Special Operations University, 2015).

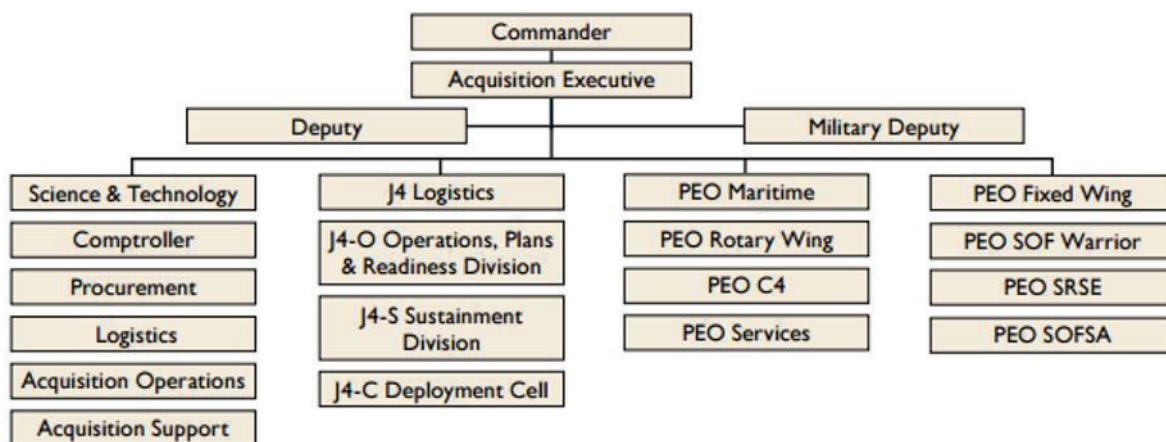


Figure 1 - Organization Structure of SOF AT&L (Joint Special Operations University, 2015)

SOF AT&L has eight Program Executive Offices (PEO) responsible for the focused acquisition and logistics needs of the SOF warfighter. Program Executive Office (PEO) Special Operations Forces Support Activity (SOFSA) is one of eight executive offices within the SOF AT&L office, and is the only PEO not headquartered at MacDill Air Force Base in Tampa, Florida. PEO SOFSA is located in Lexington, KY and is USSOCOM's dedicated total lifecycle sustainment activity to provide the SOF community with rapid, responsive, and cost effective global logistics support services (Joint Special Operations University, 2015).

PEO SOFSA provides a broad spectrum of logistical support services employing three core competencies: 1.) Streamlined Design and Rapid Prototyping, 2.) Production, Modification, and Integration, 3.) Lifecycle Sustainment Activities (Peterson, 2016). Some of the specific activities conducted by PEO SOFSA include dedicated supply chain management and maintenance for SOF peculiar (SOF-P) systems and equipment; aviation, ground, and maritime platform integration, modifications, and sustainment; and expeditionary field support services worldwide. PEO SOFSA also provides these services for other non-SOF Department of Defense and Federal Government agencies as requested to maintain critical capabilities and provide Better Buying Power solutions for the command (Defense House Publishing, 2016).

PEO SOFSA is tasked to manage and provide oversight of USSOCOM's Acquisition of Services Category 1 (S-CAT 1) Logistics Service Support Contract. The prime contractor performs the work for the Government through several hundred-task orders (contracts) for over approximately 100 SOF customers (and limited Non-SOF customers) under an overarching umbrella Indefinite Delivery Indefinite Quantity (IDIQ) logistics contract (Peterson, 2016). The partnership between the government and industry is executed through the contract and the prime contractor performs the services at a Government Owned, Contractor Operated (GOCO) complex at Bluegrass Station, Kentucky. USSOCOM leases their facilities through the Army Corps of Engineers (COE), their executive agent for leases. In addition to leasing the facilities, the Government owns all the capital equipment used for manufacturing and production activities, support and test equipment, tools, and enterprise software to manage and run the operation (Peterson, 2016).

PEO SOFSA's vision is to be recognized as the SOF community's leading choice for customer focused, logistics support (Peterson, 2016). To obtain that vision, the PEO SOFSA enterprise must be agile and efficient, keeping costs within budget. According to Mark Robinson, PEO SOFSA Finance Division Chief, the Government pays for all capital equipment, leases and utilities, therefore, the SOF customers using the contract should expect to receive competitive rates to have their acquisition and logistics requirements executed on the SOF Logistics Service Support Contract at PEO SOFSA (Robinson, 2017).

One key aspect of providing competitive usage rates for SOF customers is to ensure the overhead costs incurred by the prime contractor for activities such as warehouse operations within the Government Owned Contractor Operated (GOCO) operation are minimized to the greatest extent possible. The warehouse-operating budget is contained within the Enterprise

Logistics Pool of the overhead rates of the logistics contract. Efficiencies garnered in warehouse operations (through warehouse automation) could reduce contractor labor hours, which will reduce overall costs within the Enterprise Logistics Pool. Robinson explained this would help lower the overhead rates of the entire GOCO operation. Reducing costs to operate the GOCO operation contributes to achieving the PEO's vision of SOFSA as the SOF community's leading choice for focused, logistics support (Robinson, 2017).

The PEO SOFSA Enterprise consists of approximately 2.6M square feet of facilities at four locations separated into storage (both indoor and outdoor), administrative and production space (Mitchell, 2016). PEO SOFSA operates approximately 85% of USSOCOM's warehouse requirements to manage 48,000 line items with approximately 4 million units of property while processing about 91,000 issues, 14,000 shipments and 44,000 receipts (Special Operations International, 2015).

There are currently 13 warehouses used to store USSOCOM's equipment and supplies within the PEO SOFSA Government Owned Contractor Operated (GOCO) Enterprise. This accounts for approximately 1.0M square feet of leased warehouse space. In addition, there are an additional five outdoor storage lots making up approximately 540K square feet (Mitchell, 2016).

There are 11 warehouses on Bluegrass Station, Lexington, Kentucky, one on Blue Grass Army Depot, Richmond, Kentucky and one at USSOCOM's leased facilities on Hill Ave, Fort Walton Beach, Florida (Mitchell, 2016). Recent facility upgrades at Bluegrass Station include two state of the art 200,000 square foot warehouses.

Problem Statement

Warehouse automation at PEO SOFSA is currently limited for a variety of reasons. Further research is required to determine if there are opportunities to invest in proven commercial and Department of Defense (DoD) best practices that could be compatible with PEO SOFSA warehouse operations. Research will determine if additional warehouse automation technology used commercially, the Army, and within the Defense Logistics Agency (DLA) can improve the efficiency of SOCOM warehouses. To frame the research, the United States Special Operations Command PEO SOFSA asked the question, “What are the best practices that USSOCOM should consider using to automate our warehouses?” This is a simple question to a complex issue.

Significance of Research

The significance of this research is that the recommendation and findings in this paper could be implemented into the new USSOCOM SOF Global Logistics Service Support Contract, potentially saving the Government a significant amount of money over the period of performance of the new eight-year Indefinite Delivery Indefinite Quantity (IDIQ) contract. The new contract projected period of performance start date is 1 August 2017 (Peterson, 2016).

Literature Review

A literature review on the topic of best practices that USSOCOM should consider using to automate their warehouses includes a sampling of articles, command briefings, information papers, point papers, journal articles, and studies, and an assessment of warehouse automation best practices being used by industry, an Army SSA, and the Defense Logistics Agency. In addition, E-Research from websites and databases are included along with a number of industry-funded white papers. The research will identify the gap of USSOCOM current warehouse automation technologies compared to industry, the Army, and the Defense Logistics Agency (DLA) are today and moving in the future.

At the conclusion of the literature review, screening filters (SF) are incorporated by using the limitations of the current state of the USSOCOM warehouse operations identified in the literature review. The screening filters are used to narrow down the warehouse-automated tools presented in the literature review that best fill the gap that exists and meets the identified requirements of the USSOCOM warehouse operations.

Research Questions addressed by review

1. What automated systems / technology are being used today by USSOCOM?
2. What is the current gap that exists at USSOCOM?
3. What common warehouse automation tools are used across industry that could benefit USSOCOM?
4. What automated warehouse tools does an Army Supply Support Activity (SSA) have that could benefit USSOCOM?
5. What automated warehouse tools does the Defense Logistics Agency use that could benefit USSOCOM?

6. What best practices used by industry, the Army, and DLA are compatible with USSOCOM systems?
7. Where does it make sense to automate warehouse requirements currently performed manually?
8. What are low risk high payoff areas of automation that can be implemented by SOCOM in an incremental approach?
9. What areas require further study for long-term investment opportunities?

Current State of USSOCOM Warehouse Automation Technology and Cost

The common functions currently performed in PEO SOFSA warehouses are: receiving, storage, inspection, inventory, shipping, and disposal. The throughput of the USSOCOM warehouse operation consists of on average 40,000 receipts and 60,000 issues or shipments a year. To put that into perspective, DLA, as the preeminent defense combat logistics support agency, performs 35,000 shipments across the globe per day.

PEO SOFSA's picking operations are very limited compared to industry, the Army, and DLA. Picking operations are when warehouse technicians receive an order for a customer that requires multiple items to be retrieved from bins or shelves and placed in a container or tote.

According to Mitchell (2016), the current warehouse automation technology being used by USSOCOM at PEO SOFSA enterprise warehouses includes: limited barcode scanning, limited Radio Frequency Identification (RFID) to track OCONUS shipments, and limited automated item identification. These automation tools utilize GOLDesp Warehouse Inventory Management System (WIMS) which is the software system currently used to manage and track warehouse inventory (Mitchell, 2016).

AUTOMATION TOOLS	BARCODING	RFID	AUTOMATED ITEM IDENTIFICATION
USSOCOM WAREHOUSE			

KEY

 - Limited Capability; Used < 50%

 - Fully Implemented

Figure 2 - Current Warehouse Automation Status of PEO SOFSA (Mitchell, 2016)

The information paper states that the U.S. Government, not the prime contractor, owns all equipment, materials, and software in the warehouses to include vertical lift storage systems, material handling equipment, storage racks, furniture, and enterprise software.

According to Mitchell, whose Enterprise Division closely tracks the contractor's supply performance and costs; the current cost for conducting inventory operations at PEO SOFSA is \$1M dollars annually. There are currently 11 personnel performing inventory management functions for an estimated 21,000 labor hours per year.

The report lists the average cost to operate the PEO SOFSA Enterprise warehouses to be approximately \$11.2M per year. Over the past 18 months, there have been approximately 119 personnel performing warehouse operations at PEO SOFSA. The estimated costs of a burdened rate is approximately \$50 an hour based on a 1,880-hour man-year, is calculated to be \$11.2 M per year (Mitchell, 2016).

Commercial Practices

One of the keys to the success of the world's largest supply chains is warehouse automation. Automated warehouse technologies such as robotics and drones have eliminated many manual warehouse processes like shipping, stocking, sorting, and product inventory. Warehouse automation has increased efficiency and productivity (Pierce, 2011).

Rank	Top 10 Automated Warehouses
1	Zappos
2	Diapers.com
3	UPS Worldport
4	IKEA
5	Nike
6	FedEx
7	Amazon
8	Netflix
9	Coca Cola
10	Wal-Mart

Figure 3 - Top 10 Automated Warehouses as of 2011 (Pierce, 2011)

This research paper includes a functional review of some of the top automation and warehouse technologies currently used by many of the world's largest supply chains to ensure they remain efficient and productive in a competitive market.

Barcoding

Barcodes have been around for a long time. They were originally were used to mark railroad cars in the late 1960s. Today, you can find barcodes throughout most supply chain operations in the world. They are simple to create and use. A key advantage of barcodes is that they eliminate human error compared to manually entered data. Products can be tracked more accurately, driving inventory costs down. Barcodes can be used in a variety of ways such as placement on an individual item or a pallet to track inventory (Adams, 2014).



Figure 4 - Barcode Label (Adams, 2014)

In order to adapt the best practices in warehousing, companies need to focus on commonly available technology and business processes available today. Less than 30 percent of warehouses today take advantage of barcode technology or radio frequency identification, according to Gerald McNerney, senior director of Schaumburg, Ill. based Motorola Inc. (Bowman, 2007).

According to Evans (2016), although barcode technology has been around for a number of years, it continues to be a best practice, which provides many advantages to businesses. Prior to barcoding, clerks spent a lot of time manually entering in data about products and correcting information they did not enter in right the first time. Barcoding replaces manual data entry by enabling workers to quickly scan and identify items resulting in a reliable way to accurately read encoded information. Barcodes significantly increase the speed to process products by reducing the process of reading identification numbers to simply pointing and scanning the barcode. By simply using basic printing equipment and barcode scanners, barcode technology improves accuracy, and efficiency without a huge expense (Evans, 2016).

According to Evans, in the transportation industry, barcode scanners quickly read product information code as hundreds of packages move along conveyor belts (2016). In a barcoding environment, businesses use the technology to ensure accurate control over inventory. Warehouses scan every product that enters and departs the warehouse maintaining an accurate inventory of every item stored in the warehouse. Transportation companies scan package barcodes when receiving packages and scan the packages again upon delivery. No cost barcoding apps available for most smart phones offer inventory control at reduced costs replacing high cost and labor-intensive inventory control methods (Evans, 2016).

Radio Frequency Identification Technology (RFID)

Radio-frequency identification (RFID) is a two-part technology. It consists of both a hand held scanner and a chip referred to as a smart label or transponder. The transponders store item information and do not need to be visible to be read by wireless scanners.

RFID helps track physical inventory without the need to manually scan items. RFID scanners can be used as a security measure as well. The RFID readers are placed at entrances, exits, or checkpoints at a warehouse to track inventory. Some warehouses place RFID tags on pallets and the RFID readers at dock doors, so the pallets are automatically scanned as they pass in or out of a truck. RFID tags increase efficiencies by streamlining operations (Adams, 2014).



Figure 5 - RFID Tag (Woodford, n.d.)

According to Rosenblum, Walmart can solve its inventory problem and improve earnings by using RFID technology. Walmart lost over \$3 billion in sales in 2013 mainly due to out of stock merchandise as inventory outpaced sales. Rosenblum revealed that Walmart's store back rooms were out of control and that RFID technology could help get their inventory back under control (Rosenblum, 2014).

RFID technology was initially implemented within Walmart's supply chain in 2003. Walmart gave suppliers a suspense to have all their pallets shipped to Walmart DCs marked with RFID tags by 2006. By 2009, the effort was abandoned because at the time RFID solved no tangible problem. At the time, there were cheaper technologies such as barcoding that provided

the same solution. The initial thought was that RFID did not require line of sight to be read, however, RFID scanners cannot read through metal racks and liquids so there was not as high of a reliability rate that was initially expected, especially considering the higher costs of the RFID readers and tags (Rosenblum, 2014).

Today, however, RFID technologies have come a long way. New companies in the RFID sector have developed new readers that can provide a 40-foot diameter area scan while providing continuous coverage. In recent years, tag prices have also come down a lot. In the retail world, smaller footprint stores are able to eliminate the need to conduct manual inventories saving companies huge amounts of money (Rosenblum, 2014).

Rosenblum suggests it may be time for Walmart to reconsider using RFID technology to solve their back room problem by using a combination of new fixed readers supplemented by a few hand held devices to fix their inventory accountability problems. RFID technologies are finally ready for widespread use due to tags coming down in cost and updated readers now being able to scan larger areas. RFID technology offers improved inventory visibility and accuracy and reduced inventory investment costs (Rosenblum, 2014).

Automatic Data Collection (ADC) also called Automated Identification Technology (AIT)

A technology that goes hand in hand with barcode tags are the scanners for the tags. Barcode scanners allow the warehouse technicians to locate inventory, pick inventory when it is needed, and conduct cycle counts. Scanners with mobile computing allow warehouse workers more visibility of their inventory. The scanners increase productivity by creating a mobile interface for picking orders and receiving inventory (Adams, 2014).

The advantages of automatic data collection using barcode and radio frequency identification include increased productivity, accuracy, and lower labor costs. Even though

barcoding is a proven technology with a relatively low cost to implement, many companies still have not implemented automatic data collection. According to Harps, "Some organizations with 30,000 or 40,000 item numbers and multiple facilities are still convinced they're better off without technology" (p.3, 2005).

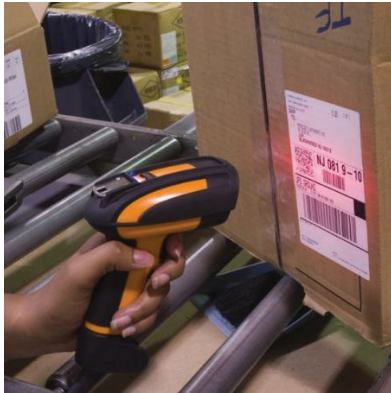


Figure 6 - Automated Identification Technology (AIT) Scanner (Carolina Barcode, n.d.)

There are several key advantages of using AIT in supply operations to include: efficiency, productivity, and accuracy. In contrast, challenges with using AIT include: potential electromagnetic interference with the proliferation of wireless devices in the warehouse and potential security concerns (McFarlane & Sheffi, 2003).

Automated Storage and Retrieval System (AS/RS)

Automated storage / retrieval systems (AS/RS) are a combination of equipment and controls which automatically handle, store and retrieve materials with speed and accuracy (Manzini, Gamberi, & Regattieri, 2006).



Figure 7 - Automated Storage and Retrieval System (Stone, 2013)

According to McLafferty (2014), the use of Automated Storage and Retrieval System (AS/RS) is a warehouse best practice. AS/RS uses automation handling devices such as conveyers, to bring products directly to the warehouse technicians rather than the technicians manually walking through the warehouse to search for then retrieve products and materials. According to the article, some of the benefits of AS/RS include: space savings, increased productivity, reduced labor, increased accuracy and can reduce inventory levels.

According to McLafferty, AS/RS is not cheap and requires an incremental implementation approach over time to be successful. Once installed, AS/RS is difficult and costly to reconfigure when changes occur. When considering AS/RS in warehouse automation, a long-view approach is required because it is expensive, is not easy to move once installed, and could take many years to see a return on investment (McLafferty, 2014).

Some of the advantages of AS/RS include: greater efficiency in high volume operations, improved inventory control, increased storage density to save warehouse space, and increased safety for warehouse workers. Some disadvantages to consider prior to making a decision of implementing AS/RS include: the complexity and enormous cost associated with the technology and the inflexible equipment reconfiguration once installed (Vasili, Tang, & Vasili, 2012).

Automated Guided Vehicles (AGVs) - Robots

Robots in warehouses are starting to become more common. Banker points to Amazon's use of over 30,000 robots in their facilities to work around the clock improving productivity and efficiency (Banker, 2016).



Figure 8 - Amazon Robots (Meadows, 2014)

This capability came about as a result of Amazon's purchase of a robotics manufacturing company called Kiva specializing in automated warehouse operations. Because of Amazon's decision to use Kiva's robotics strictly for its own use vice market sales, competitors have moved to fill the gap as the demand for robots continues to increase with the rapid growth that e-commerce places on fulfillment centers. According to Banker, "warehouse technologies that support high volumes of small, multi-line orders are receiving great interest from practitioners as they realign their capabilities to fit the changing warehouse demand profile" (Banker, 2016).

With enhanced warehouse automation technologies, there is a movement towards transitioning from a person-to-goods requirement to a demand for goods-to-person automation. This practice is accomplished by using automated shuttle systems (robots) which offer high performance as well as flexibility in performing warehouse tasks. The name given to the new shuttle systems is autonomous mobile robotics (AMR). There are a number of new robotics

systems currently under development by a number of new firms and-established warehouse automation firms focused on developing innovative new robots for a number of unique applications. Banker's article discusses several of the new small businesses developing AMR technology to include the Knapp Open Shuttle and the Locus Robotics System. Robot technology in warehouse automation is increasing productivity and efficiencies of warehouse operations (Banker, 2016).

Automated Guided Vehicles (AGVs) may have started out as simple machines that perform simple tasks in replacement of warehouse technicians, but over the past decade, AGVs have become integrated into many industries in addition to distribution centers and manufacturing such as retail, military, and healthcare businesses.

AGVs are not a good fit for every industry or every warehouse operation. To help determine whether they are the right fit for an organization, Chris Benevides analyzed the advantages and disadvantages of AGVs (2016). Some of the key advantages include reduced labor costs, increased safety, increased accuracy, and increased productivity. Benevides (2016), states disadvantages include potentially high initial investment, lack of suitability for non-repetitive tasks, and decreased flexibility of operations.

A key consideration in deciding to use AGVs is the understanding that they work according to preset systems and processes, making rapid change difficult. Therefore, warehouse models that are required agility and flexibility may not be good candidates for AGVs (Benevides, 2016).

Wireless Local Area Network (WLAN)

WLAN is a wireless computer network that links two or more devices using a wireless distribution method. Using WLAN allows device users to move around within a local coverage

area. A typical LAN is comprised of multiple components including a router / modem, switch/hub, wireless access points and wireless capable devices such as laptops, tablets or mobile computers (Carver, 2016).

According to an article written by Kokoris, wireless mobility refers to handheld or belt worn portable printers, scanners or headsets. Mobility can be applied to the following areas: receiving, cross docking, put away, returns, picking, and shipping (Kokoris, 2011).



Figure 9 - Wireless Workplace (Knab, 2013)

One of the biggest advantages of wireless networks is its ability to increase mobility within organizations. A workplace equipped with wireless LAN connectivity allows employees to move around the warehouse without any restrictions. Wireless network also allow access to all applications and documents on the network from anywhere inside the warehouse within the range of the wireless network signal. Employees can also collaborate and share information with other team members effortlessly. A wireless network provides improved access to information that resides on the servers. It also allows quick updates from anywhere inside the warehouse (Scheck, 2016).

The growth of wireless technology has changed the nature of how electronic equipment is used. Procedures originally built around a network or electrical connectivity at a fixed location

can be modified because the computing, printing, testing, weighing, and scanning technology is performed where the work is taking place. Warehouse workers as well as management have continual access to real-time information from anywhere in the warehouse (Kokoris, 2011).

Many retailers including Amazon, Home Depot, and Walmart, stock inventory and process orders from large 1 million plus square feet warehouses. All are benefiting from wireless in their warehouses, which is having a positive impact in significant efficiencies in asset tracking, inventory counts, and voice and data communications. (Botelho, 2014).

According to Bowman, a wireless warehouse enables the efficacy of workers exchanging data within integrated systems more rapidly and accurately than in a non-wireless fixed based environment. This becomes even more important in environments where tasks constantly change throughout the day. Wireless provides real-time information to managers on the status of their warehouse operations throughout the day. Wireless can support multiple portable mobile devices allowing workers freedom of movement with the warehouse, ultimately increasing productivity (Bowman, 2007).

Mobile inventory management software automates processes to handle large volumes of products moving in and out of warehouses with real-time data. Mobile inventory management software provides quick access to this data with the flexibility of wireless devices. This technology can make warehouses more efficient. There is an extensive and growing use of mobile devices shifting business applications from desktop computer to tablets (Cole, 2012).

There have been recent advancements in mobile devices, especially smartphones and tablets, which has given manufacturers more flexibility to share information in different formats. According to the article, now users can use mobile devices not only to send text messages, but

also to send pictures or maps to workers in a warehouse to verify what they are looking for more easily (Cole, 2012).

Voice Directed Picking

In general terms, picking can be defined as a warehouse activity where a small number of products are pulled from a warehousing system to meet a number of specific customer orders. Picking processes have become an important part of the supply chain process. It is the most labor-intensive and costly activity for almost all warehouse operations (Murray, 2017).

Voice picking technology uses speech recognition and speech synthesis to enable warehouse operators performing the picks to communicate directly with a Warehouse Management System (WMS). The warehouse technicians on the floor use a headset and microphone to receive instructions by voice, and then verbally confirm their actions back to the WMS (Murray, 2017).

According to Bowman, voice-directed picking is not new but has been improving and becoming more reliable. He states that voice recognition is probably the biggest technology boost seen since barcoding was introduced in warehouses over 25 years ago (Bowman, 2007). The article offers that Voice has a clear payback in gains of productivity. Bowman uses an example of a public warehousing company in Columbus that recently adopted the technology. He estimates that full payback of the system will be obtained in less than a year (Bowman, 2007).



Figure 10 - Voice Picking. (Speech Interface Design, 2015)

With traditional picking methods a warehouse technician typically has a clipboard with a paper print out of the individual items that he is required to locate and retrieve from various locations in the warehouse to order to fill customer orders. Voice picking provides many advantages over traditional warehouse picking solutions to include: provides hands free picking freeing up both hands to pick products, more efficient over traditional picking, and increased accuracy. Studies have found that moving from a traditional paper-based system to voice directed picking system could reduce picking errors by between 80 and 90 percent (Murray, 2017).

Pick to Light

Bowman highlights pick-to-light as another warehouse technology that has key advantages for those that choose to use it. Pick to light uses a series of lights positioned above pick bins to guide workers where to pull product as they are performing a kitting operation. The technology can improve efficiency of the put away of incoming shipments. According to the article, pick to light can realize savings similar to those derived from voice recognition systems. The article states that the cost rises with the number of stock-keeping units. Therefore, a high-volume operation in which a large amount of products flow into and out of the warehouse is

better suited for voice-directed picking, than a low volume operation. Bowman states that both voice-directed picking and pick-to-light systems greatly reduce the possibility of error (Bowman, 2007).

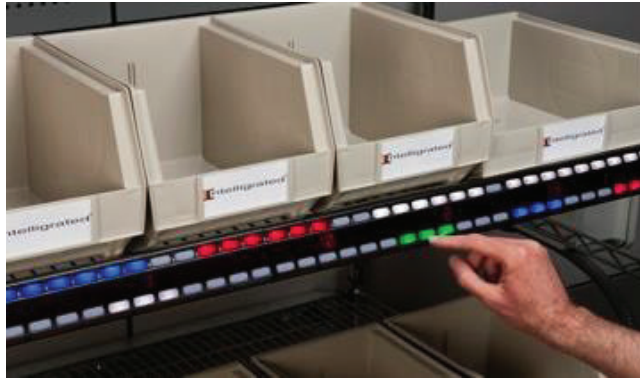


Figure 11 - Pick to Light (Material Management and Distribution, 2011)

The greatest benefits of pick to light come from use in high-density order picking warehouse operations where multiple picking locations require pickers to be both fast and accurate. Pick to light technology can enhance the picking accuracy and speed of employees (Murray, 2016).

The basic system consists of lights above the bins where employees pick. The warehouse technician scans a barcode that is on a tote or picking container, which is the customer order. Based on the order, the system will require the technician to pick an item from a specific bin location. Lights above the bins illuminate with a quantity to pick. Then the operator will select the items for the order and confirm the pick by pressing the lighted indicator. Once no further lights are illuminated, the operator knows the picking order is complete (Murray, 2016).

According to Murray (2016), a picking technology that is a competitor to pick to light is pick to voice. Pick to light can be faster than pick to voice depending on the application. Pick to light technology constantly shows the operator the quantity of the item to be picked and does not require repeated voice commands.

Murray discusses many advantages of pick to light systems to include: no language requirements as only numbers are displayed, real-time feedback on order picking and the productivity of the warehouse technician, increased throughput, as well as increased speed (2016).

The article reports that companies using pick to light systems can expect over 450 picks per hour by each operator. This is approximately ten times as fast as the picks made by a warehouse operator using a paper-based system (Murray, 2016).

Augmented Reality (AR)

Boeing experimented with an augmented reality (AR) application and head-mounted, see-through display as early as 1995, but effective and affordable hardware was not available. In the past, this technology was limited in the areas of battery life, screen size, and weight; however those constraints have been overcome through recent innovations such as Google's lightweight smartglasses (Sacco, 2016).



Figure 12 - Google Glass (Villapaz, 2015)

Boeing created a demo application of the smartglasses adapted so that a worker could use them to assemble a complex aircraft wire harness assembly. The challenge was communicating the detailed information to the worker as the information is needed in the least amount of time so that it is easy to understand. The overall goal of the project was to cut down the amount of time for the technician to go from intent to action (Sacco, 2016).

This type of application is vital to Boeing to help eliminate a production backlog of over 5,000 planes. To build the planes faster they have to figure out new efficiencies using their current workforce capacity and facilities. Smartglasses offer the promise to help achieve that end state by reducing wire harness assembly time by 25 percent in conjunction with significantly reducing human errors (Sacco, 2016).

Boeing's use of smartglasses could go far beyond the wire assembly project. Boeing researchers believe the technology could be used anywhere in manufacturing and assembly areas where paper instructions are currently being used today (Sacco, 2016).

Googleglass plans to take their technology and adapt it to logistics processes for DHL to make their product selection and packing functions more efficient. DHL plans to conduct several experiments with Exel, a freight forwarding division of Deutsche post DHL's supply-chain management business. The company will test the "smart glass" devices adapted with warehouse management software in two of their U.S. based warehouses. The purpose of the test is to replace handheld scanners and paper job orders with vision picking (Sengupta, 2015).

The article reported that Google Glass helps workers to identify the fastest route to find products by enabling barcode reading which, in turn reduces the time to pick up an item and pack it for shipping saving up to 25 percent. The technology is best suited for e-commerce warehouses. (Sengupta, 2015).

Drones

Drones, also referred to as Unmanned Aerial Vehicles (UAVs), are now becoming a reality, and have a commercial application in warehouses worldwide as companies seek to expand their levels of automation. Drones can conduct tasks that could otherwise require a large number of man-hours. One such use is barcode scanning. Many large warehouses are typically

stacked to the ceiling with inventory. This makes barcodes on items located on the highest shelving impossible to reach without the use of a lift for manual scanning. The company DroneScan has developed drones equipped with scanners capable of counting as much inventory in two days as an 80-person inventory team in three days (Transport & Logistics, 2016).

Location barcodes are placed on warehouse rack and shelving, to allow a programmed drone carrying an RF scanner to make predetermined routes through the warehouse. The drone quickly scans the rack location and the item and then immediately sends the information back wirelessly to the warehouse management system (WMS) on a computer server. This technology could save countless labor hours, reduce inventory errors, and reduce warehouse accidents (Wollenberg, 2015).

Wal-Mart is also capitalizing on drone technology. Inside their 1.2 million-square-foot distribution center near its headquarters, drones use photographic imaging pictures to ensure that all items are accounted for and in the correct location. One drone can do in one hour what it takes two employees a month to do manually. This is one of the early ways Wal-Mart sees drones playing a role in its logistics network of more than 100 distribution centers (Pettypiece, 2016).



Figure 13 - Walmart Drones Used for Inventory Management (Shedlock, 2016)

The chart below (Figure 14) provides a summary of warehouse automation tools and technology currently used by the largest supply chains within industry. While augmented reality

(AR) such as Google Glass has made great strides and has shown great promise to increase efficiency and productivity in today's modern warehouse, it still is not being widely used in the logistics area as of yet (Cirulisa & Gintersa, 2013). Drones are also showing great promise. In the future, they could be seen throughout the largest supply chains, provided the FAA permits commercial drones to operate in the National Airspace System (NAS).

AUTOMATION TOOLS	INDUSTRY WAREHOUSE
AUTOMATIC IDENTIFICATION TECHNOLOGY (AIT)	
RFID	
BAR CODING	
AGV ROBOTS	
WIRELESS	
AS / RS	
PICK TO VOICE	
PICK TO LIGHT	
WEARABLE TECHNOLOGY / AUGMENTED REALITY / GOOGLE GLASS	
DRONES UAVs	

KEY	
	- Limited Capability; Used < 50%
	- Fully Implemented

Figure 14 - Current Warehouse Automation / Technology Used by Industry

Army Practices

Automation and technology have become vital to the Army, which is currently faced with a reduced budget and force levels. These reductions are expected to continue as the Army streamlines its operations and transforms from an Army at war to an Army of preparation (Wyche, 2014).

ERP systems allow organizations to store and manage data for every stage of business. This information is shared among all users of the system, allowing near-real-time collaboration

across all business areas. The Logistics Modernization Program (LMP), initially deployed in 2010, replaces 35-year old legacy systems with a single enterprise system (Wyche, 2014). LMP is a key component of the Single Army Logistics Enterprise (SALE). SALE is an enterprise business solution that enables vertical and horizontal integration at all levels of logistics across the Army. By modernizing both the systems and the processes associated with managing the Army's supply chain at the national and installation levels, the LMP allows planning, forecasting, and rapid order fulfillment that leads to streamlined supply lines, improved distribution, a reduced theater footprint, and enhanced logistics support to the warfighter (Carroll & Coker, 2007). LMP is maintained at the national level while the Global Combat Support System Army (GCSS-Army) resides with and is maintained by tactical logisticians. Both LMP and GCSS-Army are integrated ERPs and can share information between each other (Wyche, 2014).

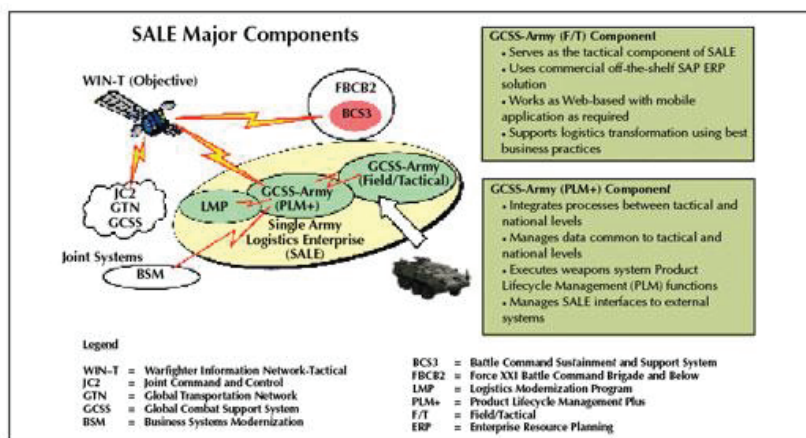


Figure 15 - SALE Major Components (Coker & Hallinan, 2006)

GCSS-A is an ERP system that combines several different automated systems into one integrated solution to provide companies, battalions, and brigades similar benefits to the national level LMP. As a single web-based system that replaces several legacy systems, GCSS-A is accessible worldwide through a web browser. This field / tactical ERP provides the backbone to

allow Army warehouse managers to wirelessly tie into the Single Army Logistics Enterprise (SALE). Another important aspect of GCSS-A is the system will provide full financial auditability and will improve readiness. It can track spending by the individual serial number of the equipment. The system saves time by simplifying data and providing real-time information allowing logisticians to solve problems quickly (Wyche, 2014).

The Army has made great strides in recent years modernizing their supply chain operations. USASOAC's Supply Support Activity (SSA) based out of Fort Campbell, KY is currently using Army approved warehouse technology to streamline and automate supply operations across their aviation enterprise. The current warehouse automation tools utilized within the USASOAC SSA include the following: Global Combat Support System – Army (GCSS-A), Very Small Aperture Terminal Satellite (VSAT), Hand Held Terminals (HHTs), RFID systems, all supported by a fully integrated wireless network. Collectively, this network provides an interconnected system that ties all aspects of logistics and maintenance for aircraft and ground systems into one enterprise system (Harbor, 2016).

GCSS-A is one single system that contains the functionality associated with the business areas of supply, maintenance, property, and finance. GCSS-Army is an integrated system that allows users with access and permission to login and perform business operations regardless of their position in the modular structure or location throughout the world. GCSS-Army is leveraging the state of the art Enterprise Resource Planning (ERP) software known as SAP (Harbor, 2016).

There are several key pieces of hardware required for GCSS-A to operate as intended. One important item is the Very Small Aperture Terminal (VSAT), which is a satellite

communication system that is designed to provide worldwide data and voice communication connectivity to, deployed, and garrison forces.

Hand Held Terminal (HHT) provides users a mobile computing device. The USASOAC's SSA is currently using Panasonic H2 tablets. The H2 tablet is a ruggedized system that provides users wireless barcode scanning ability for receipt, storage and inventory purposes. Tablets provide warehouse technicians mobile workstations making them more efficient and productive in carrying out their daily operations (Harbor, 2016).

The Radio Frequency In-Transit Visibility (RF-ITV) system traces the identity, status, and location of cargo from origin (depot or vendor) to destination via a worldwide infrastructure of RFID hardware and software. It also receives near real-time position reports for products being transported from numerous Satellite Tracking Systems (STS) such as the Army's Movement Tracking System (MTS). Data from these two technologies is combined, processed, and delivered to numerous systems and to provide global logistics support to the Warfighter. Users can also access ITV data directly through web-based maps and tracking reports (RF-ITV System, n.d.).

One of the greatest benefits of GCSS-Army is the wireless capability it provides. One of the benefits of using wireless technology in the SSA is speed. The wireless network significantly increases productivity of logisticians performing daily warehouse operations. Wireless technology allows warehouse employees to have the capability to process receipts, issue purchases, and accurately store equipment in a timely and cost efficient manner without being anchored to a desk. In addition, record accountability and accuracy are increased by using wireless technology.

AUTOMATION TOOLS	ARMY SSA WAREHOUSE
AUTOMATIC IDENTIFICATION TECHNOLOGY (AIT)	
RFID	
BAR CODING	
AGV ROBOTS	
WIRELESS	
AS / RS	
PICK TO VOICE	
PICK TO LIGHT	
WEARABLE TECHNOLOGY AUGMENTED REALITY / GOOGLE GLASS	
DRONES UAVs	
KEY  - No Capability  - Limited Capability; Used < 50%  - Fully Implemented	

Figure 16 - Warehouse Automation Technology Used by an Army SSA

Defense Logistics Agency (DLA)

In the commercial world, employees manage processes like packing inventory, loading and moving pallets, scheduling deliveries with the help the latest automation technologies (Bell, 2016). Bell, (2016), observed that the Government is lagging behind the commercial advances in distribution and automated equipment and processes. Bell, however, notes that Defense Logistics Agency (DLA) is changing to become more modernized in today's ever-changing world of technology and need for efficiency and speed.

Bell's article discusses key advancements made by DLA in the following warehouse automation areas:

- Autonomous forklifts
- Autonomous guided vehicles (AGV)

- Robotics
- Wearable technology
- Unmanned Ariel Vehicles (Bell, 2016)

According to an information paper by Jonathon Lashbrook (2016), the Defense Logistics Agency (DLA) recently consolidated all of their logistics automation initiatives under one program office, the J62. DLA is evaluating and prioritizing all automation initiatives across their enterprise and soliciting industry best practices.

DLA has wireless capabilities in the majority of their warehouses around the world. They are just now Tablets are distributed to their warehouse workers for use in the following warehouse processes: cyclic inventories, audit readiness/inventory, denials, quality assurance, and safety and supervision. These sixty-nine tablets tested across five sites are projected to increase stock readiness by up to 28% and increase inventory management by up to 12%. They are also pursuing a “web” version of their Distribution Standard System (DSS) to run on tablets and mobile devices, e.g. iPads, iPhones, etc. (Defense Logistics Agency, 2016).

These wireless capabilities open up many other efficiencies that can benefit DLA and their customers. DLA currently uses handheld wireless scan guns today in the paperless pick and pack processes and are about to initiate a full-scale pilot of voice pick (using headsets vice scan guns) at their second largest warehouse facility. DLA is also looking at the possibility of replacing scan guns with other mobile devices like iPhones sometime in the future. Wireless printing is another initiative that DLA is testing to provide a portable printing capability to reduce warehouse and customer site processing times (Lashbrook, 2016).

DLA is currently exploring several other automation technology projects such as industry's use of robotics, wearable technology benefits to include Google Glass and other VR technology, and drones (Defense Logistics Agency, 2016).

The chart below is a summary of warehouse automated tools and technology currently being used by DLA.

AUTOMATION TOOLS	DLA WAREHOUSE
AUTOMATIC IDENTIFICATION TECHNOLOGY (AIT)	
RFID	
BAR CODING	
AGV ROBOTS	
WIRELESS	
AS / RS	
PICK TO VOICE	
PICK TO LIGHT	
WEARABLE TECHNOLOGY AUGMENTED REALITY / GOOGLE GLASS	
DRONES UAVs	
KEY  - No Capability  - Limited Capability; Used < 50%  - Fully Implemented	

Figure 17 - Warehouse Automation Technology Used by DLA

Figure 18, below is a summary of the key warehouse automation tools and technology currently used by supply chain giants in industry, a modern Army SSA, and the DLA.

AUTOMATION TOOLS	USSOCOM WAREHOUSE	ARMY SSA WAREHOUSE	DLA WAREHOUSE	INDUSTRY WAREHOUSE
AUTOMATIC IDENTIFICATION TECHNOLOGY (AIT)				
RFID				
BAR CODING				
AGV ROBOTS				
WIRELESS				
AS / RS				
PICK TO VOICE				
PICK TO LIGHT				
AUGMENTED REALITY / GOOGLE GLASS				
DRONES UAVs				

KEY

-  - No Capability
-  - Limited Capability; Used < 50%
-  - Fully Implemented

Figure 18 - Combined Warehouse Automation Technology Used by USSOCOM, Army, DLA, and Industry

The warehouse automation tools and technology advantages and disadvantages discussed above are summarized below in figure 19 below and are further discussed in the screening filter process.

AUTOMATED TOOLS	ADVANTAGES	DISADVANTAGES	REFERENCES
AUTOMATIC IDENTIFICATION TECHNOLOGY (AIT)	Increased Productivity Increased Accuracy Increased Efficiency	Potential electro mag interference Potential security concerns Cost of implementation	McFarlane, D., & Sheffi, Y. (2003). Harps, Leslie (2005, May)
RFID	Non line of sight scanning Labor Reduction Asset Tracking Robust and Durable	Cost of tags Cost of new infrastructure Concern of return on investment	McCarthy, L. (2004).
BAR CODING	Affordable Easy to use Inventory tracking Reliable and accurate	Limited to line of sight scan Limited visibility Restricted traceability Not durable	McCarthy, L. (2004).
AGV ROBOTS	Reduced labor costs Increase safety Increased accuracy	High investment cost Not suitable for non-repetative tasks Decreased flexibility	Benevides, C. (2016, November 7)
WIRELESS	Flexibility Improves efficiency Asset tracking in real time Real time coms with employees	Connectivity challenges Signal propagation Roaming Security Concerns	Botelho, J. (2014) Caver, A. (2016)
AS / RS	Provides more storage space Reduces labor costs Increases safety	High investment cost Not suitable for non-repetative tasks Decreased flexibility	Vasili, M. R., Tang, S. H., & Vasili, M. (2012)
PICK TO VOICE	Different languages can use Hands-free/eyes-free Reduced training time	Cost is higher than RF Scanning and Visual Log Not suited for low velocity operations	Jones, R. (2007) Murray, M. (2017)
PICK TO LIGHT	Improves accuracy Increases efficiency Easy to train	Requires WMS Cost is higher than Voice, RF Scanning, and Visual Log Not suited for low velocity opns	Jones, R. (2007) Murray, M. (2016, November 19)
AUGMENTED REALITY / GOOGLE GLASS	Increased efficiency Increased handling safety Increased worker safety Increased asset up time	Expensive Security Concerns Discomfort Still in development	Gonzalez, A. (2014, January 8) Jhajharia, S., Pal, S. K., & Verma, S. (2014) Cirulisa & Gintersa, (2013)
DRONES UAVs	Increased efficiency Reduction in labor hours Speed of delivery / inventory Increased safety of workers	FAA restrictions Cost of drone fleet Durability Can't carry heavy items	McNeal, G. (November 7, 2014). Paul, Fredrick (March 23, 2015). Pettypiece, S. (2016, June 2).

Figure 19 - Advantages and Disadvantages of Warehouse Automation Technology

Applying Screening Filters to Narrow Down the Viable Warehouse Automation Options for USSOCOM Requirements

Although many of the warehouse automation and technology tools presented in the literature review show positive results in speed, efficiency, labor hour expenditure, accuracy, asset visibility, and warehouse footprint, etc. supply chain applications, it is important to assess the fitness of these tools for the USSOCOM supply chain operations.

The literature review highlighted several limitations of the USSOCOM warehouse operations. Based on SOF customer requirements, PEO SOFSA warehouse operations need to be flexible and agile. The warehouses need to be reconfigurable based on mission requirements.

PEO SOFSA warehouse operations also have limited requirements for large scale picking operations. Also, the overall throughput of warehouse issues and receipts is limited compared to DLA and industry warehouse operations. These identified limitations of PEO SOFSA Warehouse operations make many of the warehouse automation technologies highlighted in the literature review not feasible for USSOCOM requirements. The chart below identifies the Screening Filters (SF) used to down select a portion of the automation tools that are not compatible with the current USSOCOM warehouse operations mission.

SCREENING FILTERS (SF)	DESCRIPTION
1	Supports highly flexible warehouse operations
2	Supports low throughput warehouse operations
3	Supports limited warehouse picking operations
4	Technology is stable and proven

Figure 20 - Initial Warehouse Automation Screening Filter

SF-1 - “Supports highly flexible warehouse operations”. USSOCOM customers need PEO SOFSA warehouse operations to be flexible as warehouse requirements can and do change with little prior notice. USSOCOM warehouses support SOF customers from the PEOs and PMs from SOF AT&L to the logisticians at the Components and Theater Special Operations Commands. These customers have a wide scope of requirements for warehousing to include: yard storage, rolling stock, dormant stock, rack storage, floor storage, Controlled Cryptographic Items (CCI), high dollar sensitive items such as weapons, and some rapid throughput requirements. The indications are that future SOF customer requirements will continue to call upon PEO SOFSA Warehouse operations to be agile and responsive (McBride, 2017).

SF-2 - “Supports low throughput warehouse operations.” The throughput of companies such as Coca-Cola, Amazon, Wal-Mart, and the Defense Logistics Agency (DLA) are orders of magnitudes higher than USSOCOM warehouse operations. The throughput of the USSOCOM

warehouse operations consists of on average 40,000 receipts and 60,000 issues or shipments per year. To put that into perspective, DLA performs 35,000 shipments across their global enterprise every day (Mitchell, 2016). There are automation technologies that can provide huge benefits to high throughput supply chain operations like DLA's a global network of distribution centers where automation such as sophisticated AS / RS (conveyer belts, mini load cranes, and carousels); however, such technology is a poor investment for USSOCOM due to having a much lower warehouse velocity requirements.

SF-3 - "Supports limited warehouse picking operations". Picking operations are a typical function performed in warehouses across industry and the Department of Defense. PEO SOFSA has very limited picking operations. The highest volume picking operation executed at PEO SOFSA is the SOF Personal Equipment Advanced Requirements (SPEAR) program. Based on 2016 data, 99,000 lines are visually picked per year at PEO SOFSA, which further breaks down to 1,900 lines per week or just 5 lines per hour (Mitchell, 2016).

SF-4 - "Technology is stable and proven", ensures that the automation technology considered is stable and proven prior to attempting to procure and implement it into PEO SOFSA warehouse operations.

Figure 21, below, shows the results of applying the screening filters to the identified warehouse automation tools and technologies.

AUTOMATED TOOLS	SF1 Supports Flexibility	SF2 Supports Low Throughput	SF3 Supports Limited Picking Operations	SF4 Technology Maturity Level	Remarks
AUTOMATED ITEM IDENTIFICATION	●	●	●	●	AIT Meets All Screening Filters
RFID	●	●	●	●	RFID Meets All Screening Filters
BAR CODING	●	●	●	●	Bar Coding Meets All Screening Filters
AGV ROBOTS	●	●	●	●	AGV Robots are not ideal for: flexibility, low throughput, and limited picking.
WIRELESS	●	●	●	●	AIT Meets All Screening Filters
AS / RS	●	●	●	●	AS / RS are not ideal for: flexibility, low throughput, and limited picking.
PICK TO VOICE	●	●	●	●	PICK to VOICE is not ideal for limited picking operations.
PICK TO LIGHT	●	●	●	●	PICK to Light is not ideal for limited picking operations.
AUGMENTED REALITY	●	●	●	●	Augmented Reality is very promising but is not a fully mature technology yet.
UAVS	●	●	●	●	Drones are very promising but are not a fully mature technology yet.

Key

● - Passed Screening Criteria

● - Failed Screening Criteria

Figure 21 - Screening Filters Applied to Initial Warehouse Automation Technologies

AGV (Robots) failed to pass three of the four screening filters (SF1-3). First, AVGs did not pass SF1- “Supports highly flexible warehouse operations”. According to Benevides (2016), AGVs perform to preset systems and processes. This can make flexible warehouse conditions difficult. AGVs also did not pass SF2 – “Supports low throughput” or SF3 – “Supports limited picking operations”. AGVs are best suited for high volume, repetitive tasks, utilized for multiple shifts (Benevides, 2016).

AS/RS failed to pass three of the four screening filters (SF1-3). AS/RS are best suited for extremely high volume, repeatable tasks. Due to their size, weight, and extensive installation requirements, AS/RS are inflexible to changing warehouse requirements once installed (Vasili, Tang, & Vasili, 2012).

Pick to voice and pick to light both failed the screening filter to support limited picking operations (SF-3). Voice pick and light pick technologies do not have a recognizable impact in a low-volume warehouse operation (Jones, 2007). Therefore, it is not cost effective to integrate the automation technology into USSOCOM's limited picking warehouse operations.

AR failed screening filter SF4- "Technology is stable and proven". AR such as Google Glass, is still in development and is not yet fully integrated into mainstream industry warehouse operations. For example, an AR pilot product for logistics was delayed due to a lack of hardware equipment for real time tracking of technicians in a warehouse environment (Cirulisa & Gintersa, 2013).

Drones also failed screening filter SF4 – "Technology is stable and proven". The Federal Aviation Administration (FAA), who controls airspace regulations within the United States, will not allow Amazon to continue research in the United States due to the recent crackdown on air regulations. Until the FAA figures out how they will regulate commercial drones in the U.S., Amazon has relocated its R&D to England (Wollenberg, 2015). In addition, Wal-Mart continues to explore the use of drones in their warehouses to more accurately and efficiently account for products in inventory. Drones used for this purpose are still in testing, however, Wal-Mart sees this technology playing an important future role in its logistics network of more than 100 distribution centers and over 4,500 stores across the country (Pettypiece, 2016).

Following the application of the screening filters, figure 22 depicts the automation technologies that remain as viable solutions for USSOCOM warehouse operations.

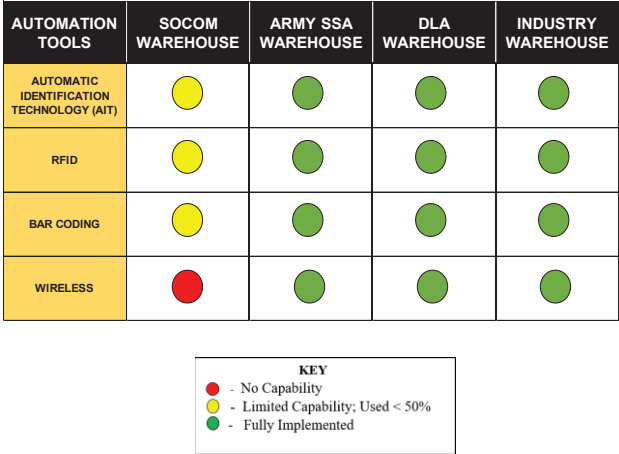


Figure 22 - Warehouse Automation Technologies That Remain

Research Methodology

Overview

The objective of the research is to identify the current “as is” status of automation in USSOCOM warehouses, understand what drove the current state, then determine the “to be” state. A literature review of existing best warehouse automation practices used by the largest commercial supply chains, an Army SSA, and the Defense Logistics Agency (DLA) was conducted. The intent of this paper is to provide a broad review of the automation tools and technology USSOCOM should be aware of that exists today. At the conclusion of the literature review, screening filters are identified to narrow down the warehouse automated tools presented that best fill the gap that exists and meets the identified requirements of the USSOCOM warehouse operations.

Literature Review Focus and Approach

The literature review is divided into five sections. The first section provides a review and establishes a current “as is” state of the current warehouse operations being utilized by USSOCOM today at their PEO SOFSA facilities in Lexington, KY. The second section reviews the many automation technologies and tools used by the world’s largest supply chains in industry. The intent of this section is to provide an overview of automation technologies used for awareness but may not be feasible for the USSOCOM warehouse operations. The third section, provides a functional review of warehouse automation technologies used by an Army Supply Support Activity (SSA). The fourth section reviews current and future innovations of warehouse automation used by the Defense Logistics Agency. The literature review closes by establishing Screening Filters (SF) obtained by applying the current limitations of the PEO SOFSA warehouse operations to pare down the many warehouse automation technologies

discussed in in sections 1 - 3 that show promise for filling the current gap for USSOCOM warehouse operations.

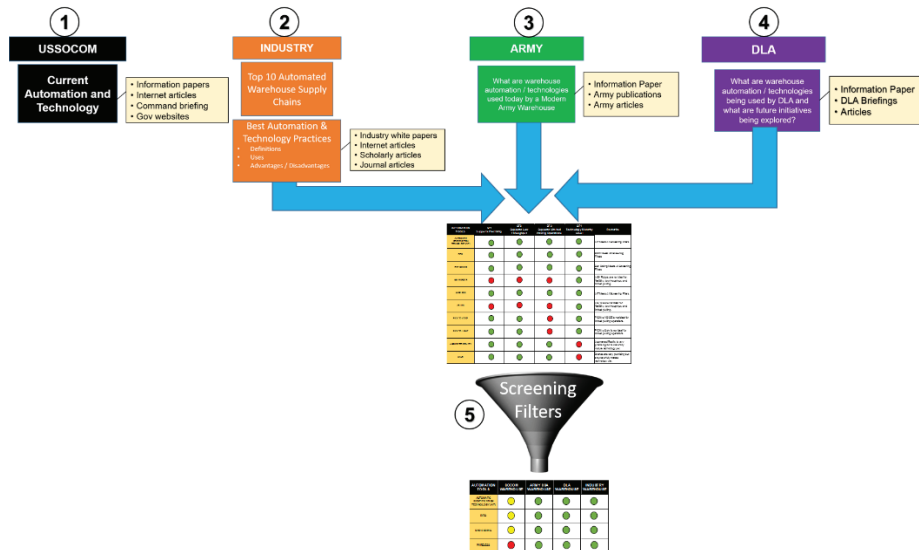


Figure 23 - Literature Review and Approach

Limitations of the Study

There are a number of limitations in the context of this research paper. The timeframe and the size limitations of this research project did not allow an extensive stakeholder analysis of all USSOCOM customers and warehouse managers that run the warehouses of PEO SOFSA Logistics Service Support Contract or of industry, the Army, and the Defense Logistics Agency. This analysis would have allowed research to identify and address industry and stakeholder concerns with implementing specific warehouse automation technology. The information used in this analysis could have been in the form of a stakeholder survey. This did not detract from the research but would have been worthy of inclusion to this research.

This research paper provided a high-level functional review of prevailing warehouse automation technology used today by industry, a modern Army Supply Support Activity (SSA), and the Defense Logistics Agency; therefore, it was not necessary to conduct a detailed

quantitative analysis. An in-depth quantitative analysis would have provided more solid findings through exploring real-world experience of warehouse automated technology fielding and included detailed financial and managerial details. This detailed information would have more thoroughly provided a Return on Investment (ROI) assessment of the best warehouse automation practices used by industry, which would have added to this research.

Another limitation of this research paper is that it does not explore and discuss the warehouse software required for many automation tools. The selection and implementation of Warehouse Management Software (WMS), Warehouse Control Software (WCS), or Warehouse Execution Software (WES) is required to take full advantage of many of the automation technologies, (e.g. voice pick, pick to light, AGVs, AS/RS, robots, wearable technology, etc.) discussed in this research paper (Roberto, 2016). GOLDesp is the current Warehouse Inventory Management Software (WIMS) used by PEO SOFSA today (Mitchell, 2016). Further research and discussion are required to determine if there are better-automated warehouse software solutions that may be more beneficial to USSOCOM.

Other limitations not addressed in this research paper are the important considerations involving software integration of selected warehouse software (WIMS, WMS, WCS, or WES) and its compatibility with Enterprise Resource Planning (ERP) software. Currently, the ERP in use at PEO SOFSA is Jobscope (Mitchell, 2016). There may be better solutions available that USSOCOM should consider. This paper touches on the fact that Army is currently using SAP as their ERP and DLA is researching the benefits of implementing SAP to make their logistics operations more efficient as well.

A final limitation of this research paper is a lack of research and discussion of all the coordination and approvals required when adding new software or a wireless network onto a

government enclave. This requires the authorization and approval of the Authorizing Official (AO) in accordance with DoD Risk Management Framework (RMF) and other associated DoD and contractual requirements (Federal Business Opportunities, 2016). This is not a trivial manner and requires detailed planning and coordination in order successfully integrate automation technology onto a government network.

Data Analysis and Findings

Identifying the USSOCOM Warehouse Automation Gap

The filtered results for the top warehouse automation technologies that show promise for application to USSOCOM's warehouse operations are depicted in Figure 22 – Warehouse Automation Technologies That Remain. Of the four warehouse automation tools and technology that passed the screening filters, three (AIT, bar coding, and RFID) of the four are already being used by USSOCOM, but on a limited basis. The gap that exists between warehouse automation that passed the screening filters (Figure 22) and the current status of PEO SOFSA warehouse automation tools and technology (Figure 2) is the lack of an integrated wireless network, depicted below in figure 24.

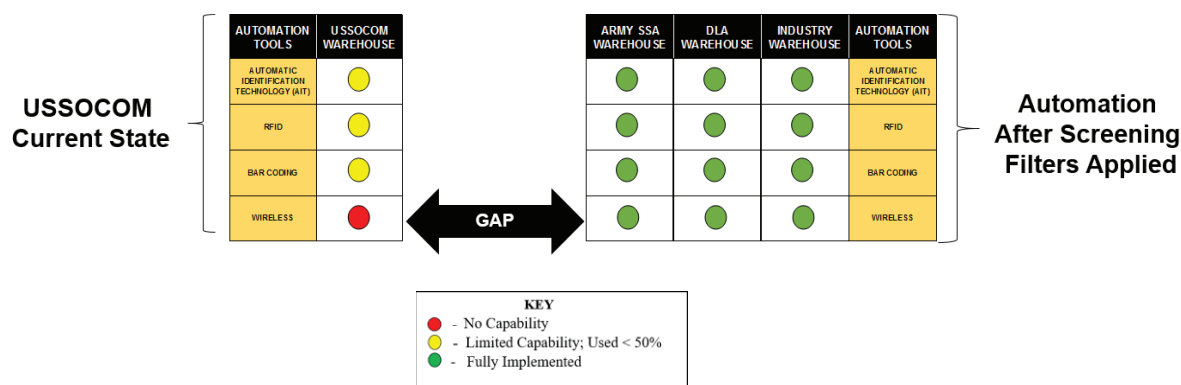


Figure 24 - USSOCOM Gap in Automation Technology

USSOCOM's Logistics Operations Objectives

In further analyzing whether a wireless network should be integrated into USSOCOM's warehouse operations, it is important to consider the command's objectives for its logistics operations. The most recent Performance Work Statement (PWS) for USSOCOM's new SOF Global Logistics Support Services contract highlights three key logistics operations objectives: provide accurate inventory accountability, provide asset visibility, and maximize efficiencies (Federal Business Opportunities, 2016).

LOGISTICS OBJECTIVES	DESCRIPTION
1	Maintain Accurate Inventory Accountability
2	Provide Asset Visibility
3	Maximize Efficiencies in Logistics Operations

Figure 25 - USSOCOM Logistics Objectives (Federal Business Opportunities, 2016)

Wireless Networks and its efficacy to USSOCOM Logistics Operations Objectives

Wireless is becoming more and more prevalent in today's modern warehouses. The Army is using wireless throughout their global enterprise and has recognized the benefits it offers. Harbor (2016), highlights one of the greatest benefits of GCSS-Army is the wireless capability it provides. The wireless network significantly increases productivity of logisticians performing daily warehouse operations. Wireless technology allows warehouse employees to have the capability to process receipts, issue purchases, accurately store, and account for inventory in a timely and cost efficient manner. In addition, Harbor states that record accountability and accuracy are increased by using wireless technology (Harbor, 2016)

DLA also takes advantage of the benefits of a wireless network in the majority of their warehouses. In addition, DLA is in the process of distributing tablets to their warehouse workers for use in various warehouse functions such as cyclic inventories, audit readiness/inventory, denials, quality assurance, and safety and supervision. Initial results suggest wireless will increase their stock readiness by up to 28% and increase inventory management efficiency by up to 12% (Lashbrook, 2016).

Wireless provides other efficiencies beneficial to DLA and their customers. Examples include replacing scan guns with other mobile devices like iPhones or wireless printing to provide a portable printing capability thus reducing warehouse and customer site processing times (Lashbrook, 2016).

Wireless allows workers to exchange data within integrated systems more rapidly and accurately than in a non-wireless fixed based environment. This becomes even more important in environments where tasks constantly change throughout the day. Wireless also allows managers to have real-time information on the status of their warehouse operations throughout the day. Wireless can support multiple portable mobile devices, allowing workers to get out away from their desk and be more productive (Bowman, 2007).

Amazon, Home Depot, and Walmart, are all benefiting by having Wi-Fi in their warehouses which is having a positive impact on asset tracking, inventory counts, and voice and data communications. A wireless environment has enabled many commercial organizations to significantly increase warehouse efficiencies (Botelho, 2014).

A wireless network will greatly increase the functionality and efficiency of the other automation tools that USSOCOM is currently using, e.g. bar coding, RFID, and AIT systems. Wireless AIT associated with barcoding and RFID technology, all but eliminates the possibility of human error, and allows employees to be mobile without being tethered to a PC. Warehouse technicians can quickly identify packages and items with a high rate of speed, accuracy and efficiency (Evans, 2016).

Conclusions & Recommendations

Conclusions

The research takes a broad approach and breaks down the initial question of “What are the best practices that USSOCOM should consider using to automate their warehouses?” by looking at key automation tools and technologies being used by industry, an Army SSA, and the DLA. Screening filters were used to establish a framework to reduce the number of automation possibilities discussed in the literature review to only those warehouse automation technologies applicable to USSOCOM warehouse requirements. These are depicted in Figure 22 - Warehouse Automation Technologies That Remain. Of the four automated technologies that remained, all but Wireless Network are already being partially utilized in PEO SOFSA warehouse operations today.

By using the key logistics operations objectives taken from the most recent PWS for USSOCOM’s new SOF Global Logistics Support Services contract which are: provide accurate inventory accountability, provide asset visibility, and maximize efficiencies (Federal Business Opportunities, 2016), the analysis showed that USSOCOM should strongly consider implementing a wireless network into their supply chain operation.

Wireless and the mobile technologies that a wireless network supports, have significantly increased the efficiency and productivity of warehouse operations across industry, the Army, and DLA. A wireless environment allows organizations real-time warehouse operations analytics and allows technicians to efficiently count and track inventory and improve order accuracy (Botelho, 2014). The Army, DLA, and industry have all seen the benefits that wireless can bring to their warehouse operations. Wireless and the host of mobile computing technology to include tablets, wireless scanners (AIT), and wireless printing, that it supports is

scalable and can be expanded and added to over time. Many of the automation technologies explored in this research, (e.g. pick to voice, pick to light, AGV Robots, mobile technologies, and AR), require a wireless network and associated warehouse software. By establishing a wireless network, USSOCOM could position itself to take advantage of future automation capabilities as its warehousing needs change over time.

Recommendations

Recommendation 1. Implement a wireless network into the PEO SOFSA logistics enterprise to best meet the needs of the logistics operations objectives listed in Figure 25 - USSOCOM Logistics Objectives.

Recommendation 2. Maximize the use of bar coding throughout the PEO SOFSA warehouse operations. Although barcode technology has been around for a number of years, it continues to be a best practice, which provides many advantages to businesses. With basic printing equipment and barcode scanners, organizations can use barcode technology to improve accuracy, speed and efficiency without a huge expense (Evans, 2016).

Recommendation 3. Maximize the use of RFID technology throughout the logistics enterprise to take full advantage of the asset tracking capability it provides, especially for USSOCOM's sensitive, high dollar and OCONUS shipments.

Recommendation 4. Fully implement AIT in PEO SOFSA warehouse operations. AIT scanners are a technology that goes hand in hand with barcode tags. AIT capabilities enable paperless identification, automatic data entry, and digital retrieval of supply data. AIT has a wide range of technologies available to include simple barcodes to radio frequency identification technology (Defense Acquisition University, n.d.)

Recommendation 5. USSOCOM should consider further research to examine the benefits of updating the current ERP (Jobscope), and implement a WMS to seamlessly integrate business processes with logistics operations throughout the overall enterprise. An ERP can improve visibility by sharing common data across the enterprise, and provide access and real time information (Rogers, 2011). A WMS communicates with workers on handheld RF devices and supports the integration of voice technology. The software is also capable of providing a way to track and report productivity. WMS can update inventory and communicates data for the movement of material from storage to the active pick locations ensuring that pickers do not run out of inventory (Rogers, 2011). The alternative is to keep the current ERP (Jobscope) and WIMS (GOLDesp) (Mitchell, 2016).

References

- Adams, W. (2014, March 17). *5 warehouse technologies that can save time and money*. Retrieved from Evans Distribution Systems: <https://www.evansdist.com/5-warehouse-technologies/>
- Alvarez, J., Nalepa, R., Wyant, A.-M., & Zimmerman, F. (2015). *Special Operations Forces Reference Manual*. MacDill AFB, Florida: The JSOU Press Fourth Edition.
- Banker, S. (2016, January 11). *Robots in the warehouse it's not just amazon*. Retrieved from Forbes: <http://www.forbes.com/sites/stevebanker/2016/01/11/robots-in-the-warehouse-its-not-just-amazon/#21f900192f80>
- Bell, J. R. (2016, April 16). *Domo arigato mr. roboto*. Retrieved from Defense Logistics Agency: <http://www.dla.mil/AboutDLA/News/NewsArticleView/Article/743732/domo-arigato-mr-roboto/>
- Benevides, C. (2016, November 7). *The Advantages and Disadvantages of Automated Guided Vehicles (AGVs)*. Retrieved from Conveyco: <http://www.conveyco.com/advantages-disadvantages-automated-guided-vehicles-agvs/>
- Botelho, J. (2014, February 10). *Wireless in the Warehouse*. Retrieved from Enterprise Networking Planet: <http://www.enterprisenetworkingplanet.com/netsp/wireless-in-the-warehouse.html>
- Bowman, R. (2007, May 01). *Best tools for warehouse management are hiding in plain sight*. Retrieved from Supply Chain Brain:

- <http://www.supplychainbrain.com/content/technology-solutions/all-technology/single-article-page/article/best-tools-for-warehouse-management-are-hiding-in-plain-sight/>
- Carolina Barcode. (n.d.). *Corded Barcode Scanner Types*. Retrieved from Carolina Barcode: <https://www.carolinabarcode.com/corded-barcode-scanner-types-a-68.html>
- Carroll, K., & Coker, D. (2007). *Logistics Modernization Program: A Cornerstone of Army Transformation*. Retrieved from Army Logistician: http://www.almc.army.mil/alog/issues/JanFeb07/lmp_cornerstone.html
- Carver, A. (2016, December 22). *Benefits of wlan implementation in the warehouse*. Retrieved from Datex Corp: <http://www.datexcorp.com/benefits-wlan-implementation-warehouse>
- Cirulisa, A., & Gintersa, E. (2013). Augmented reality in logistics. *Procedia Computer Science*, 26(2013), 14-20.
- Coker, D. W., & Hallinan, J. G. (2006). *A Logistician's Primer on GCSS-Army (PLM+)*. Retrieved from Army Logistician: http://www.almc.army.mil/alog/issues/may-june06/logistic_primer.html
- Cole, B. (2012, May 7). *Mobile inventory management brings visibility, flexibility to the warehouse*. Retrieved from Tech Target: <http://searchmanufacturingerp.techtarget.com/news/2240149777/Mobile-inventory-management-brings-visibility-flexibility-to-the-warehouse>
- Comptroller, Department of Defense. (2016, April). *Financial improvement and audit readiness (fiar) guidance*. Retrieved from Comptroller - Department of Defense: http://comptroller.defense.gov/Portals/45/documents/fiar/FIAR_Guidance.pdf

Datalogic. (2013). *White Paper: benefits from warehouse automation: a comparative report*.

Retrieved from Datalogic: <http://www.datalogic.com/upload/marketlit/wp/WP-WAREHOUSEAUTOMATION-ENA4.pdf&ved=0ahUKEwjwttnx2ZzRAhUCSyYKHeOsDrcQFggdMAA&us>

Defense Acquisition University. (n.d.). *Defense Acquisition Guidebook*. Retrieved from Defense

Acquisition University: <https://acc.dau.mil/CommunityBrowser.aspx?id=489755#5.3.4>

Defense House Publishing. (2016, March 18). *Update on special operations forces global*

logistics support services contract. Retrieved from Defense House Publishing:

<http://www.defense-house.com/defense-news/update-on-special-operations-forces-global-logistics-support-services-contract/>

Defense Logistics Agency. (2016, October 5). *Distribution Modernization Program*. Honolulu, Hawaii.

Evans, K. (2016). *What are the benefits of using barcode technology?* Retrieved from Chron:

<http://smallbusiness.chron.com/benefits-using-barcode-technology-58387.html>

Federal Business Opportunities. (2016). *Special Operations Forces Global Logistics Support*

Services (SOF GLSS). Retrieved from Federal Biz Ops:

https://www.fbo.gov/index?s=opportunity&mode=form&id=2993e08bda35fe5a966afc80aa452d6d&tab=core&_cview=1

Fiveash, C. (2016, January). *Warehouse automation: the next generation*. Retrieved from

Inbound Logistics: <http://www.inboundlogistics.com/cms/article/warehouse-automation-the-next-generation/>

FW Warehousing. (2011). *Rfid and barcodes: which wireless technology rules the warehouse?*

Retrieved from FW Warehousing: <http://www.fwwarehousing.com/rfid-and-barcodes-which-wireless-technology-rules-the-warehouse/>

Glenn, D. (2013, September 22). *The move to automated warehouses: is it worth the investment?*

Retrieved from Business 2 Community: <http://www.business2community.com/product-management/move-automated-warehouses-worth-investment-0623214#HV17vuYrzsJbItBg.97>

Gonzalez, A. (2014, January 8). *Wearable Devices: The New User Interface for Logistics*

Software. Retrieved from Talking Logistics:
<http://talkinglogistics.com/2014/01/08/wearable-devices-new-user-interface-logistics-software/>

Harbor, S. (2016). *Warehouse automation tools and practices of the united states army special operations aviation command (USASOAC) supply support activity (SSA)*. Fort Campbell, KY.

Harps, L. (2005, May). *Best Practices in today's distribution center*. Retrieved from Inbound

Logistics: <http://www.inboundlogistics.com/cms/article/best-practices-in-todays-distribution-center/>

Holzworth, C. (1997). *Operation eagle claw: a catalyst for change in the american military*.

Research Paper submitted to Marine Corps Command and Staff College.

Jhajharia, S., Pal, S. K., & Verma, S. (2014). Wearable computing and its application.

International Journal of Computer Science and Information Technologies, 5700-5704.

Joint Special Operations University. (2015). *Special Operations Forces Reference Manual*.

MacDill AFB, Florida: The JSOU Press Fourth Edition.

Jones, R. (2007, January 24). *Voice-direct picking: pros and cons*. Retrieved from The Balance:

<https://www.thebalance.com/pick-to-voice-warehouse-systems-2221457>

Knab, E. (2013, February 27). *Why WMS?* Retrieved from We Are the Practitioners:

<http://www.wearethepractioners.com/library/the-contributors-voice/2013/02/27/why-wms->

Kokoris, G. (2011, January 10). *The benefits of wireless mobility in your warehouse or dc*.

Retrieved from Logistics Management:

http://www.logisticsmgmt.com/article/the_benefits_of_wireless_mobility_in_your_warehouse_or_dc1

Lashbrook, J. (2016). *Defense Logistics Agency initiatives in warehouse automation*. On file at the DLA J62 Program Office: Defense Logistics Agency.

Logic Material Handling. (n.d.). Retrieved from Logic Material Handling:

<http://logicmaterialhandling.com/products/order-fulfillment-software/voice-directed-picking/>

Manzini, R. G. (2006). Design and control of an AS / RS. *The International Journal of Advanced Manufacturing Technology*, pp 766-774.

Manzini, R., Gamberi, M., & Regattieri, A. (2006). Design and control of an AS/RS.

International Journal of Advanced Manufacturing Technology, 28(7), 766-774.

doi:10.1007/s00170-004-2427-6

Material Management and Distribution. (2011). *Intelligrated pick-to-light system for dynamic pick face*. Retrieved from Material Management and Distribution:

<http://www.mmdonline.com/products/intelligrated-pick-to-light-system-for-dynamic-pick-face/>

McBride, M. S. (2017, Jan 18). *Flexible and Agile Warehouse Operations*. Lexington, Kentucky.

McCathie, L. (2004). *The advanatages and disadvantages of barcodes and radio frequency in supply chain management*. New South Wales: University of Wollongong Thesis Collections.

McFarlane, D., & Sheffi, Y. (2003). The Impact of Automatic Identification on Supply Chain Operations. *The international journal of logistics management*, 14(1), 1-17.

McLafferty, J. (2014, July 8). *DMW&H*. Retrieved from Best practices to follow when automating your warehouse.: <http://www.dmwandh.com/warehouse-automation/asrs/>

McNeal, G. (2014, November 7). *Six things you should know about amazon's drones*. Retrieved from Forbes: <http://www.forbes.com/sites/gregorymcneal/2014/07/11/sixthings-you-need-to-know-about-amazons-drones/>

Meadows, C. (2014). *Amazon's Kiva robots herald warehouse automation*. Retrieved from Teleread: <http://teleread.com/amazons-kiva-robots-herald-warehouse-automation/>

Michel, R. (2016, February 1). *logistics management*. Retrieved from Six best practices for better inventory management:
http://www.logisticsmgmt.com/article/warehouse_dc_management_six_best_practices_for_better_inventory_management

- Mitchell, T. (2016). *Current status and cost of operation for PEO special operations forces support activity (SOFSA) warehouses*. . Lexington, KY: Point paper on file.
- Murray, M. (2016, November 19). *Pick to light warehouse systems*. Retrieved from Logistics and Supply Chain Management: <https://www.thebalance.com/pick-to-voice-warehouse-systems-2221457>
- Murray, M. (2017, January 8). *Pick to Voice Warehouse Systems*. Retrieved from The Balance.
- Murray, M. (2017, January 8). *Pick to Voice Warehouse Systems*. Retrieved from The Balance: <https://www.thebalance.com/pick-to-voice-warehouse-systems-2221457>
- Paul, F. (2015, March 23). *10 reasons amazon's drone delivery plan still won't fly*. Retrieved from network World: <http://www.networkworld.com/article/2900317/wireless/10-reasons-amazons-drone-delivery-plan-still-wont-fly.html>
- Peterson, S. L. (2016, May 23). PEO Special Operations Forces Support Activity (SOFSA) Command Briefing. Lexington , Kentucky, Fayette.
- Pettypiece, S. (2016, June 2). *Wal-Mart is trying out drones in its warehouses*. Retrieved from Bloomberg: <https://www.bloomberg.com/news/articles/2016-06-02/wal-mart-s-distribution-center-drone-hints-at-automation-plans>
- Pierce, F. (2011, March 8). *The Top 10 Automated Warehouses*. Retrieved from Supply Chain Digital: : <http://www.supplychaindigital.com/warehousing/1789/The-Top-10-Automated-Warehouses>
- RF-ITV System*. (n.d.). Retrieved from US Army AMIS: http://www.usarmyamis.army.mil/Systems/RF-ITV/rfitv_system.html

- Roberto, M. (2016, March 1). *WES Solutions: More than a Bridge*. Retrieved from Modern Material Handling: http://www.mmh.com/article/wes_solutions_more_than_a_bridge
- Robinson, M. (2017). *PEO SOFSA Logisitics Overhead Rates*. Information Paper, Lexington.
- Rogers, L. K. (2011, November 1). *Supply chain software basics: supply chain execution*. Retrieved from Modern Materials Handling:
http://www.mmh.com/article/supply_chain_software_basics_supply_chain_execution
- Rosenblum, P. (2014, May 22). *How walmart could solve its inventory problem and improve earnings*. Retrieved from Forbes:
<http://www.forbes.com/sites/paularosenblum/2014/05/22/walmart-could-solve-its-inventory-problem-and-improve-earnings/#2f71c623240c>
- Sacco, A. (2016, July 13). *Google Glass Takes Flight at Boeing*. Retrieved from CIO:
<http://www.cio.com/article/3095132/wearable-technology/google-glass-takes-flight-at-boeing.html>
- Scheck, S. (2016, Novemeber). *Impact of Wireless Technology in the Workplace*. Retrieved from Small Business Trends: <https://smallbiztrends.com/2016/11/wireless-technology-in-the-workplace.html>
- Sengupta, R. (2015, August 17). *Google glass used in vision picking, scanning and paper work for DHL logisitics services*. Retrieved from International Business Times:
<http://www.ibtimes.com.au/google-glass-used-vision-picking-scanning-paper-work-dhl-logistics-services-1460827>

Shedlock, M. (2016). *What Do Inventories Suggest About 3rd Quarter GDP? Can Drones Cure the "Inventory Crisis"?* Retrieved from Mish Talk:

<https://mishtalk.com/2016/08/04/what-do-inventories-suggest-about-3rd-quarter-gdp-can-drones-cure-the-inventory-crisis/>

Speech Interface Design. (2015). *Voice Picking the Ultimate Solution*. Retrieved from Speech Interface Design: <http://www.speech-interface.com/sid-blog/voice-picking-the-ultimate-solution>

Stone, S. (2013). *Industrial Automation and The Flexibility Problem*. Retrieved from Cisco Eagle: <https://www.cisco-eagle.com/blog/2013/08/22/industrial-automation-and-the-flexibility-problem/>

Transport & Logistics. (2016). *10 warehousing tech innovations from around the world*. Retrieved from Transport Exhibitions: <http://www.transport-exhibitions.com/Market-Insights/Cold-Chain/Archive/Warehousing-Innovations-New-Technology>

Vasili, M. R., Tang, S. H., & Vasili, M. (2012). Automated storage and retrieval systems: a review of travel time models and controls policies. In R. Manzini, *Warehousing in the Global Supply Chain* (pp. pp. 159-209). Springer London: Springer-Verlag.

Villapaz, L. (2015). *What Google Needs To Do To Fix Glass And End The 'Glasshole' Stigma*. Retrieved from International Business Times: <http://www.ibtimes.com/what-google-needs-do-fix-glass-end-glasshole-stigma-1790398>

Wollenberg, V. (2015, October 27). *Drones are making soaring advancements in the material handling industry*. Retrieved from Conveyco: <http://www.conveyco.com/drones-are-making-soaring-advancements-in-the-material-handling-industry/>

Woodford, C. (n.d.). *RFID frequency (RF and RFID tags)*. Retrieved from Explain that stuff!:

<http://www.explainthatstuff.com/rfid.html>

Wyche, L. D. (2014, May). *The impact of enterprise resource planning systems on army sustainment*. Retrieved from GCSS - Army:

<http://gcss.army.mil/Library/TopStories/ImpactSustainment.aspx>

Acronyms

Acronym	Description
AMR	Autonomous Mobile Robotics
AR	Augmented Reality
AS/RS	Automated Storage and Retrieval Systems
DCs	Distribution Centers
DLA	Defense Logistics Agency
ERP	Enterprise Resource Planning
GCSS-A	Global Combat Support System – Army
HHT	Hand Held Terminals
IDIQ	Indefinite Delivery Indefinite Quantity
LMP	Logistics Modernization Program
MAIS	Major Automated Information Systems
NAS	National Airspace System
PEO SOFSA	Program Executive Office Special Operations Forces Support Activity
PWS	Performance Work Statement
RFID	Radio Frequency Identification
RMF	Resource Management Framework
S-CAT 1	Acquisition of Services Category 1
SOF AT&L	Special Operations Forces Acquisition Technology and Logistics
SOF-P	Special Operations Forces Peculiar
STAMIS	Standard Army Management Systems (STAMIS)
UAV	Unmanned Aerial Vehicle
USASOAC	United States Army Special Operations Aviation Command
USSOCOM	United States Special Operations Command
VSAT	Very Small Aperture Terminal Satellite
WCS	Warehouse Control System
WES	Warehouse Execution System
WIMS	Warehouse Inventory Management Software
WLAN	Wireless Local Area Network
WMS	Warehouse Management System

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