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CURRENT INDUSTRY STANDARD RADIO FREQUENCY IDENTIFICATION (RFID) TRACKING: SAFER, CHEAPER, MORE EFFICIENT

by

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Abstract

Radio Frequency Identification (RFID) technology has advanced greatly in the last fifteen years, providing greater applications at decreased cost when compared to years previous. Applications of RFID technology include asset tracking, tool accountability, work-in-process tracking, and inventory management, among a myriad of other established uses and future applications. In commercial industry, RFID technology has been proven to increase safety, improve efficiency of operations, thus reducing operating costs. Although the Air Force has seen some success in implementing RFID technology, there has yet to be a solution that has been implemented Air Force-wide. This research paper investigates the advancements in RFID technology over the last fifteen years and seeks to determine whether or not an RFID application can be implemented Air Force-wide to improve safety, efficiency, and reduce operating costs.

This research used an evaluation framework to explore current RFID technology, its past and present use within the Department of Defense, and the ability to implement an RFID solution Air Force-wide under the unique operating restrictions faced by the Department of Defense when compared to commercial industry. Although RFID technology has improved drastically over time while also seeing a reduction in costs to implement, there are many reasons why an Air Force-wide RFID solution is challenging. Ultimately, this research concluded that RFID technology cannot feasibly be implemented on a service wide scale, but should be pursued at the unit level for successful application and improvements in safety, efficiency, and operating costs.

INTRODUCTION

Overview of the Study

Today, Radio Frequency Identification (RFID) systems are used for access control, payment systems such as a toll road speed pass, smart cards, and anti-theft devices and in some of the largest retailer supply chains in the world such as Albertsons, Metro, Target, Tesco, and Wal-Mart.[1] The Department of Defense (DOD) has also stated intentions of using this technology for supply chain tracking. In December 2004, Electronic Product Code Global, a non-profit organization with several participating countries, charged with setting the Electronic Product Code system ratified the second-generation standard, which paved the way for the broad adaptation of this technology.[2]

The Air Force Sustainment Center (AFSC) at Robins Air Force Base, Georgia operates one of three sustainment complexes in the Air Force.[3] Responsible for approximately 70 percent of Air Force contract dollars, the AFSC is responsible for world-class depot maintenance, supply chain management, and installation support for C-130s, C-5s, C-17s, E-8s, F-15s, U-2s, MQ-9s, Special Operations Forces, Automated Test Equipment, Support Equipment and Vehicles, Electronic Warfare and Avionics, as well as Armament.[4] In 2008, the AFSC developed an RFID system to track critical aircraft components and tools, saving the Air Force money and improving safety.[5] The technology was first considered in 2003 when the Air Force requested a better method of tracking fragile and costly gyroscopes, critical to aircraft navigation systems.[6] The system, developed by David Carrick, Cynthia Gunter, and Whitfield Samuel, was named the Global Enterprise Tracking (AFGET) system.[7] The AFGET system could handle assets ranging from aircraft and ground vehicles to toolkits and parts.[8] At the time of implementation, however, the use of active RFID systems was still cost prohibitive for the Air Force, but the AFSC system

was employed at five other bases and was seen as the expected standard solution for Air Force-wide application.[9] Eventually, the AFGET system appears to have failed to take off Air Force-wide and faded away at the AFSC. This study seeks to readdress RFID technology and recommend its reimplementation within the Air Force to increase savings, efficiency, and safety. This will be accomplished through a case study analysis of the AFGET system to determine what worked and what caused its ultimate failure, as well as analysis of current technology that has exponentially advanced since AFGET system failure, in addition to other DOD implementation considerations.

Nature of the Problem

Radio frequency identification tracking technology needs to be reevaluated for its implementation Air Force-wide to save money and improve efficiency and safety. This technology had evolved dramatically within the last ten years and has fewer barriers to entry compared to when previous attempts at implementation were made in the Air Force, due to improved technology and lower costs. Some may argue that RFID tracking technology has already been attempted on a large scale, was too costly, failed, and should not be attempted again. However, since then, the exponential growth of technology in accordance with Moore's Law, coupled with the Electronic Product Code Global's (a non-profit organization with members from several countries) ratification of the second-generation standard for RFID technology has made the broad adaptation of this technology a cost-effective endeavor today.[10] The problem is that it appears that the Air Force has not attempted to utilize this technology Air Force-wide with today's technological advancements and lower costs of entry.

Purpose of the Study

The purpose of this study is to evaluate the current industry standard RFID technology, and whether or not it can be acquired and implemented Air Force-wide. Just as Moore's law describes the exponential growth of transistors in a dense integrated circuit; similar trends can be observed in the advancement of digital electronics in general.[11] It was only a decade ago that the smartphone made its debut with Apple's iPhone. Given this rate of technological evolution, it is time for the Air Force to reevaluate the use of RFID systems in their daily operations. Although RFID technology may have been cost prohibitive in years past, an affordable user-friendly or automated system can improve efficiency, save money, and improve safety. It will investigate systems previously utilized by the DOD, and will attempt to recommend applications and plans for implementation into today's force. It will include an investigation into current RFID technology and commercially available products, as well as analyze case studies of previous DOD systems, and current aerospace industry standard case studies and practices available through the RFID Journal and Advancing Identification Matters, Global organizations.

Research Question

Technological developments, lower costs of entry, and myriads of examples of successful implementation of RFID tracking technology in the private sector give proof that this technology can improve the Air Force's costs, safety, and efficiency. Therefore, the research question for this study is whether or not aerospace industry standard RFID tracking systems can be implemented Air Force-wide, and if so, how?

Research Methodology

This research will use the evaluation framework to explore RFID technology and the ability to implement it Air Force-wide. It will evaluate past attempts by the Air Force to implement this technology on a large scale and why they may have failed. Additionally, it will consider successful case studies of how the technology can solve problems to enhance safety, efficiency, and cost savings. After analyzing the past, present, and future of this technology, this paper will make recommendations on whether RFID technology can be implemented Air Force-wide or not, and if not, conclude with recommendations on the way ahead.

LITERATURE REVIEW

History

The roots of radio frequency identification can be traced back to World War II.[12] German pilots would roll their aircraft to change the ground radar frequency returns, thus allowing ground radar operators to identify friend versus foe; this was the first passive RFID system.[13] Later, Watson-Watt headed a British secret project that developed the first active RFID system that placed transmitters on British aircraft that broadcasted a signal back to ground radar systems to identify the aircraft as friend or foe.[14] In the 1970s, the United States government developed an active RFID system for the tracking of nuclear material within the Department of Energy, which was also adapted and utilized by the Department of Agriculture to track cows.[15]

In the 1990s, IBM developed an Ultra High Frequency (UHF) RFID system to be used in applications ranging from warehouse tracking to farming, but at the time, the technology and implementation were cost prohibitive, thus resulting in failure to commercialize the system and a sell-off of the patents.[16] In 1999, this UHF RFID system got a boost when the Uniform Code

Council, European Article Number International, Proctor & Gamble, and Gillette put forth funding to establish the Auto-ID Center; an Internet-like structure to track goods globally.[17] Between 1999 and 2003, researchers at the Massachusetts Institute of Technology ran with the technology and changed the way people thought about RFID within the supply chain and the Auto-ID Center gained the support of over 100 end-user companies, as well as the Department of Defense.[18]

Advancements in Technology

Over fifteen years have now passed since RFID started gaining traction. Today, RFID technologies are being deployed by companies of every size to improve efficiency, visibility, reduce shrinkage, in addition to other benefits.[19] Today's RFID technology has evolved into a variety of systems to solve different tracking problems. As discussed in the history of RFID, there are both passive and active low frequency, high frequency, and ultra high-frequency RFID tracking systems. A passive system uses high power readers that send out a low frequency, high power signal to paper thin, adhesive, battery-free tags such as the ones seen in Figure 1.[20] The tag is energized by this signal and activates its electronic circuit, which transmits coded information back to the reader.[21] This type of technology is most often used for inventory tracking

Figure 1. Passive RFID Tracking Tags.

An active RFID tracking system uses battery-powered tags that broadcast their embedded information across access points or readers.[22] Active RFID tracking is useful for monitoring the physical location of an object that may move, where passive RFID tracking is more appropriate for an inventory that does not move.[23] The least expensive of the two types of systems is the passive system, where tags cost anywhere from 7 to 10 cents each, whereas active tags can range between 5 and 15 dollars each.[24,25] A semi-passive RFID tag mostly operates like the passive tag, but with a battery, which can boost the tags readable signal (also referred to as a semi-active or battery-assisted tag).[26] Further subsets of these RFID tracking systems include infrared, WiFi (electromagnetic wave) assisted systems, LiFi systems (visible light spectrum), Bluetooth Low Energy (BLE), or hybrid systems combining different types together into one system.[27]

These types of RFID tracking systems and their associated technology are not new however, which begs the question: why look to implement this technology now? The biggest reason is the development of this technology over time and the reduced costs associated with its

implementation and utilization. When Apple introduced the Macintosh personal computer in 1984, it sold for $2,500 and had a 32-bit processor.[28] Compare that to today's technology, where a mobile smartphone has more computing power than what was used to send a man to the moon. As technology improves according to Moore's Law, it becomes smaller, cheaper, and more powerful with each iteration. It is for this reason of affordability that RFID technology is now a viable solution for businesses and organizations of all sizes and should be re-evaluated for use within the Air Force.

Further developments are still being made in the RFID industry today. Market predictions estimate that the industry will grow to $24.5 billion by 2020, and that continued price drops will place RFID tags at five cents each.[29] As other technologies are developed or improved, so will this technology. A prime example of this would be the advancements in battery technology, which could allow for paper thin active RFID tags and longer battery lifetime, reducing required real-estate for tag placement as well as costs of active tags. A great example of continued technological advancement is the RFID tag developed by E Ink Corp and Fujitsu Semiconductor. These two companies have developed an electronic ink smart label that requires no battery, and its data can be updated as a product moves through the supply chain to display information about the package, barcodes, or myriads of other data points.[30] These tags are re-usable and customizable with respect to their size and resolution, which reduces paper waste as well as the cost of tags over the long term.[31]

Figure 2. E-ink battery free RFID Tag.

Case Study: Stadium

Stadium, a small sports apparel retail store with 3,800 employees and 173 storefronts believed that their inventory accuracy was 99.5 percent before RFID tracking.[32] Events that affected their inventory accuracy included things such as incomplete training, stressed staff, old difficult hardware, complicated IT systems, temporary staff, and poor communication from the head office.[33] After implementing a pilot program in two stores for three months, Stadium improved their inventory accuracy from the actual 65 percent to 97 percent and in turn, showed increased sales with higher inventory accuracy. Sales were also increased with the use of the Geiger counter function of the RFID readers, which locates a specific product via its RFID proximity alerts, directing the user to the specific product in real time.[34] The use of this feature

eliminated back stock searching for items, increasing rapid availability for customers in the store, resulting in more purchases.

Case Study: Air Force Global Enterprise System

The 78th Communications Group at Robins Air Force base first considered RFID in 2003 to better track and inventory fragile and costly gyroscopes; components critical to various aircraft navigation systems that require frequent servicing.[35] Technology experts from the 78th Communications Group, David Carrick and Cynthia Gunter, partnered with Whitfield Samuel of Computer Sciences Corp. to develop RFID tracking and a management infrastructure to improve the asset tracking process at facilities nationwide.[36] The Air Force Global Enterprise Tracking system integrated multiple technologies into a single interface, enabling asset tracking ranging from airframes to specialized toolkits and components.[37] Active Global Positioning System (GPS) tags were used to track substantial assets such as aircraft and vehicles, to allow for real-time position tracking, while passive tags were used on smaller assets for cost efficiency.[38] The application of this system worked well for the Air Force because it permitted precise tracking of specific and individual parts that would be removed, serviced, and then replaced on a specific aircraft.[39]

It took three years for AFGET to gain momentum at Robins Air Force Base when the system expanded beyond a single office tracking 25 gyroscopes in a 4,500-6,000 square foot building, to a system that covered over one square mile of indoor and outdoor storage and tracked over 15,000 assets.[40] The expansion of AFGET however, was slow and methodical despite Air Force maintenance groups nationwide learning of the boosts to efficiency and reductions in cost and wanting to implement the system within their units.[41] The developers wanted to ensure that the system performed consistently under real-world conditions on a limited

scale before presenting it for implementation on a larger scale.[42] Eventually, over several years, up until 2008 AFGET was integrated into five other facilities: Tinker Air Force Base, Hill Air Force Base, Wright-Patterson Air Force Base, and the Aerospace Maintenance and Regeneration Group at Davis-Monthan Air Force Base. The success of the system during this time, centered around AFGET's interactive database system, linking various databases across the nation as well as its flexible and adaptable design that could handle different locations and their unique tracking requirements.[43] This interconnectivity allowed for asset tracking from one base to another without having to swap tags.

The prime reason for implementing AFGET was to prevent costly mistakes in aircraft maintenance that can either cost hundreds of thousands of dollars at best, or lives at worst. An aircraft wing replacement kit can cost more than $600,000, and toolboxes average $30,000 each.[44] Cost savings were realized through asset tracking that prevented acquiring excess inventory as well as trimming down excess inventory to improve efficiency and reduce overhead costs.[45] Efficiency gains were realized through the time savings afforded by instantly locating critical assets, even as big as entire aircraft, which can be hard to locate on vast properties, especially when stripped down of identifying markings while undergoing depot level maintenance. Another benefit of AFGET was the ability to track and monitor assets that are vulnerable to harsh environmental conditions such as high or low temperature and humidity levels.[46] GPS tracking tags provided in-depth vehicle data for monitoring maintenance vehicles such as tugs, cranes, and loaders. This data included not only its location, but things like engine RPM, mileage, and fuel level, which helped to ensure these assets were serviced and ready to perform their unique tasks when needed.[47]

The impacts of AFGET were seen in several areas at Robins Air Force Base. The precision measurement equipment laboratory reduced the number of days in its work-in-process through accurate tracking and availability of test equipment.[48] Ground support equipment savings were realized through decreased inventory and maintenance costs, with maintenance productivity increased due to the ability to quickly located and transfer equipment to the point of use. Vehicle support also showed a reduction in the required inventory and more efficient maintenance tracking with remote status updates of transmissions, electrical systems, fuel level, and mileage among others. AFGET claimed the 2008 GCN Award for "Government Agency IT Achievement." "GCN delivers technology assessments, recommendations, and case studies to support Public Sector IT managers who are responsible for the specification, evaluation, and selection of technology solutions."[49]

Despite the reception and success of AFGET within the maintenance community, its success was not immediate. The team at Robins Air Force Base encountered and had to overcome several challenges when implementing this system. The immediate challenges of setting up the system included optimizing both tag and readers' durability and safety issues. The physics of radio waves operating near large machinery as well determining ideal placement of tracking devices so that they did not interfere with maintenance duties required in-depth planning, specific to each building in which they were utilized.[50] Along with the ideal placement of tracking equipment, was the ideal placement of the tags themselves, to ensure accurate and useful tracking within the facility.[51] The durability of the tags themselves was also important, as assets may undergo acid baths, pressure washing, and painting. The most cost-effective and durable solution for this problem was found with tags produced by WhereNet.[52] With respect to the safety of both assets and personnel, Intrinsically Safe certified tags and trackers ensured that

there would be no risk of fire or shock, especially in open-fuel areas, by ensuring the technology was not combustible, electrically unsound, liable to fall off, or had protruding parts that could hurt people or damage equipment.[53] Lastly, an analysis had to be conducted to determine precisely which assets were worth tracking to save money, enhance safety, or provide another tangible benefit.[54]

AFGET Today

Despite the seeming initial success of AFGET within the Air Force, with its test bed at Robins Air Force base and eventual expansion to five other Air Force Bases around the nation, it appears to have stalled at some point along the way. The latest article from Robins Public Affairs dated in 2015 stated that 6,500 items are tracked across Robins Air Force base through RFID, down from the purported 15,000 items during the expansion of the program in 2006.[55] The system was however expected to expand to track more than 50,000 items.[56] This alone may not be proof of a dwindling system. The reduction in tracked items could be yet another case for efficiency, where analysis and practice determined that not as many assets required RFID tracking. There was also, however, very little expansion of AFGET Air Force-wide between 2008 and 2015. While still utilized at three of the original expansion units, Hill, Tinker, and Davis-Monthan Air Force Bases in 2015, AFGET was not on record as being utilized by Wright Patterson Air Force base any longer.[57] Bringing the total number of bases back up to the original five seen by 2008, Joint Base San Antonio now uses AFGET for asset tracking.[58] The fact that AFGET and its potential is recently being touted as a "huge step from the way business has been done in depot maintenance in the last few decades" is further evidence that the system never took off after its initial development in 2003.[59]

RFID Challenges in the Air Force Today

Mr. Kenneth Morgan is the Engineering and Force Protection, (Information Technology) IT Integration Branch Chief at Headquarters Air Force A4. He spoke at the RFID Journal LIVE! Conference in 2017 relating the Air Force's progress with RFID to the global RFID community including end users, leading vendors, systems integrators, consultants, and others. In his briefing, Mr. Morgan presents several challenges that the Air Force faces while trying to implement current RFID technology into its operations. Currently, the Air Force is utilizing this technology for asset visibility, supply chain transactions, aircraft and equipment ground operations, and lifecycle management of components.[60] An example of successful implementation of passive RFID was done with clothing and equipment issue at basic training. After clothing and equipment issue is complete, the trainee passes through a scanner that takes inventory of all issued items via RFID tags to ensure both inventory tracking and proper issue to the trainee.[61] This application improved efficiency and doubled throughput in the clothing and equipment issue process.[62] While examples of RFID implementation on a small scale, such as the one above, can be found abundantly and successfully, there are challenges that the Air Force faces when trying to implement systems Air Force-wide.

Although AFGET found some success at Robins Air Force base, and even at other large logistics centers across the Air Force, the operationalization of the system down to a unit level is hard to do because individual units do not have the economies of scale that the large sustainment center has.[63] There are also challenges in standardization across the enterprise when trying to implement a system Air Force-wide; using one version of software and processes that integrate into that system without smaller units requiring specifically tailored edge ware. While there are challenges when trying to operationalize a system down to the unit level because of its relatively

small size, similarly, there are challenges trying to create an Air Force-wide system as well, simply because of its sheer size. Commercial industry successfully implements RFID, even on a large scale (Walmart as an example), but the Air Force dwarfs these comparison scales. The Air Force supply chain is more extensive than thirteen commercial supply chains.[64] Our fleet of 5,137 aircraft is five times larger than a commercial fleet of an airline.[65] For comparison, Delta Air Lines has one of the largest airline fleets in the world, totaling 879 aircraft as of 30 November 2018.[66] Another vital comparison to make is the fleet type and its mission. Where Delta Air Lines has a fleet of a small number of different types of aircraft serving one mission: passenger and cargo transportation, the Air Force operates 57 different aircraft, all with different missions including airlift, air refueling, reconnaissance, fighters, and bombers to name a few.[67]

Mr. Morgan also explains the challenges associated with implementing systems within the DOD. What he calls a "panoply of mandates," complicates the implementation of new technology, whether it be legal restrictions or cybersecurity restrictions, there are approximately five or six gates that any technology system must pass through before it is accredited and approved for use.[68] To the Air Force's advantage, there is reciprocity across the branches of the military; so if the Navy, for example, achieves accreditation for an IT system, the Air Force can use that accreditation as well, or at least use it as a foundation for modification.[69] Another limitation on the Air Force is the budget available for IT. Walmart spends thirteen times the amount of money on their IT supply than the Air Force;[70] a result of a for-profit corporation improving processes to achieve higher profits versus the Air Force with finite resources and budgetary constraints. Lastly, considering the budgetary constraints which limit IT procurement and the mandates which slow its implementation, the Air Force's IT has an average age of eighteen years, where many mainframe systems date back to the 1960s.[71] Given these

constraints, agile tech insertion for the Air Force is a vastly different time scale compared to the commercial industry. The Air Force IT cycle time is measured in years (5.9-7.3 years) versus the commercial industry where the IT cycle time is measured in weeks (6 weeks).[72]

RFID products and services that work in the commercial industry do not readily meet Air Force requirements necessarily. A myriad of factors must be considered when assessing an RFID solution within the Air Force. Location is the first consideration; a system that works in garrison, may not be suitable for deployed operations.[73] Accessing the database is another issue, whether it is accessed on a .com or .mil site, or whether it contains classified information and must operate on a secure network is a challenge.[74] The devices used within the RFID system must be robust and to military specifications for wear and tear as well as the operating environment.[75] There are also risks associated with operations security. Passive tags on weapons, for example, may be discoverable and traceable by the enemy, resulting in their ability to locate forces on the battlefield.[76] Operating systems used in the RFID system need to be device agnostic and cross-platform capable.[77] It can take a commercial provider eighteen months and approximately $150,000 to get through the testing required to meet the mandates and standards of the DOD unless that company has a sponsor.[78] Commercial RFID providers must come to the table with a solid understanding of the constraints that the Air Force operates within so that the correct IT solution can be paired with the problem with which it is tasked to solve. These industry service providers must also understand that their solution to meet one problem is not scalable to the whole Air Force because of the budgetary and mandate limitations.

The future state vision of the United States Air Force with respect to RFID according to Mr. Morgan, consists of five key points, with an overall standpoint that innovation happens at the end user point of the process. The first is to work on integration and interoperability both within

the Air Force as well as with joint partners.[79] Second is a modernization of mobile devices used within the system using phones, tablets, Chromebooks as well as their associated operating systems such as iOS, Android, and Windows.[80] The third is to adopt low-cost external peripherals such as sleds, Bluetooth, built-in cameras or universal serial bus (USB).[81] Fourth is to modernize the mobile application platform to develop applications and get them out to the end user for rapid implementation (6-month timeline).[82] Last is expanding the wireless networking footprint to support these RFID systems, whether it is base communications infrastructure or a commercial broadband provider of land and wireless communications.[83]

RFID-IV Indefinite Delivery Indefinite Quantity Contract

The DOD awarded the "RFID-IV Contract" in 2014 to Savi Technology Inc. (Savi), an asset-management technology company. Savi is the sole provider for the RFID-IV contract (#W52P1J-14-D-0014) in addition to being the only provider in previous versions RFID-I, -II, and –III, totaling more than $800 million.[84,85] The DOD awarded $102 million in the –IV contract to Savi for "Active Radio Frequency Identification hardware, software, documentation, and incidental service to authorized government users worldwide" to include training, warranty, and technical engineering services through 6 April 2017 with options to extend the contract.[86] The DOD recently exercised the final option year through 7 April 2019, where Savi is introducing a "lighter, easier-to-maintain, portable, deployment kit with state of the art electronics."[87] This contract is utilized by the DOD, U.S. Coast Guard, North American Treaty Organization (NATO), coalition partners, and other federal agencies, both CONUS and OCONUS, and also meets Foreign Military Sales requirements to provide interoperability with allies.[88] Last month, two DOD agencies placed an additional order for 48,000 active RFID tags, in addition to the 1 million already deployed by the DOD and other international militaries.[89]

According to the most recent data, the Air Force approved eight of Savi's RFID tags for use aboard all sizes and classifications of fixed-wing and rotary-wing aircraft while transporting supplies.[90] Testing had to be accomplished to reduce the risk of electromagnetic interference with aircraft systems. The approved tags transmit microwatts of power intermittently in short data packets, which were deemed safe for air travel.[91]

The Defense Logistics Agency (DLA) is the latest DOD agency with a plan to adopt RFID tracking for supply chain management. DLA's order, which is part of the DOD RFID-IV contract with Savi, will track approximately 24,000 military assets which primarily consist of vehicles.[92] The deployment of the Savi technology solution will take place at the Red River Distribution Depot in Texas, which is only one of the agency's eight depots.[93] The Red River Distribution Depot is the storage site for the U.S. Army's Bradley Fighting Vehicle Systems, several rocket systems, as well as multipurpose wheeled vehicles.[94] This order will use larger (4.9 inches by 13.3 inches), solar-powered sensors (with a five to 10-year battery), that will transmit real-time tracking data to Savi's Visibility, a real-time asset location, and analytics software program.[95] With two daily updates to location and transmitter battery life, these transmitters will send their data to the cloud-based Visibility program which is then forwarded to the DOD's Radio Frequency-In Transit Visibility (RF-ITV) infrastructure, a web-based solution for tracking.[96] This data allows managers to view assets within their supply chain to determine delays and misroutes, resulting in accurate anticipation of asset arrival at a specific destination.[97] With global coverage via the transmitters cellular transmissions, man hours spent tracking inventory are significantly decreased, allowing personnel to tend to more pressing tasks.[98] Savi's chief marking officer Vicki Warker Savi's claims that this contract indicates that the government is in fact on the "bleeding edge" of technology adoption, despite suggestions otherwise.[99]

RFID in the Aerospace Industry

In 2012, Boeing started an RFID program to automate aircraft maintenance tasks. Specifically, their RFID solution accounts for life support equipment aboard commercial aircraft, including inspection for the presence of life vests and integrity of their seal, oxygen generators, and loose emergency equipment in the airline cabin.[100] These daily, weekly, and monthly maintenance checks, known as A-checks or C-checks in Federal Aviation Administration (FAA) terms, can take an entire 8-hour shift to complete or up to 10 hours on a wide-body aircraft.[101] With this one RFID-enabled process, Boeing was able to perform presence, security, and serviceability checks independently or simultaneously in just a few labor minutes. A conservative estimate of 85 percent increase in efficiency and lead-time reduction.[102] Given the criticality of aviation-related inspections, the FAA approval process to adopt this RFID solution was long and laborious. Boeing teamed up with Japan Airlines in 2007 to demonstrate that this process was safe as well as effective.[103] The final step in Boeing's actual implementation of this process was to gain FAA certification for RFID tags to serve as an authoritative source for maintenance compliance requirements.[104] With that certification granted, Boeing could use RFID data as a trusted source of information and sign of maintenance task cards using that data.[105]

The global aerospace, defense, and security company BAE Systems recently launched an RFID-based solution with the objective of automating inventory replenishment, managing tools, and tracking work-in-process.[106] BAE is using RFID tags to track more than 200,000 assets, 30,000 parts, and 6,500 work orders within its plants.[107] Their main goal was to improve manufacturing production efficiency, which would improve delivery times and decrease operational costs.[108] The material management process involved changing the supply process

from one that pushes materials into stock based on forecasts to a pull methodology based on just-in-time demand.[109] Specifically, material bins with RFID tags are moved when empty, which exposes the passive tag to a fixed or handheld reader, which then sends a signal to the supplier that restock is required.[110] These orders are automatically generated every night and delivered at a pre-determined time.[111] Their tool tracking solution uses RFID readers on the assembly floor, tracking tools that enter a specific zone as well as those that return. The software solution allows employees to control which zone's tools are permitted to enter or leave, track them via floor plan map, and can even provide an alert if an unauthorized movement occurs, via cellular text message if desired.[112] The work-in-process tracking system uses RFID tags attached to printed work orders, tracking them as they move around the production floor, updating the system each time they pass through a read zone, a process that can help to identify bottlenecks.[113] BAE Systems' solution is sensor-agnostic and operating system flexible, running on dedicated servers or on the cloud.[114] A similar system of Automated Identification Technology deployed across 50 Boeing assembly sites has saved over $100 million during the first year alone, and BAE Systems is striving for similar results.[115] Future plans for BAE Systems include launching portal readers at engineering labs, supporting chemical management, automating tracking of perishable materials, and providing expiration alerts as well as device audit validation.[116]

Assuring Valuation, Accountability, and Control of Government Property

The Department of Defense Office of the Under Secretary of Defense (Acquisition, Technology & Logistics) publishes a document titled "Department of Defense Guide to Uniquely Identifying Items: Assuring Valuation, Accountability, and Control of Government Property." The Government Accountability Office (GAO) describes the challenges faced by managers of Federal Government property:

> GAO and other auditors have repeatedly found that the federal government lacks complete and reliable information for reported inventory and other property and equipment, and cannot determine that all assets are reported, verify the existence of inventory, or substantiate the amount of reported inventory and property. These longstanding problems with visibility and accountability are a major impediment to the federal government achieving the goals of legislation for financial reporting and accountability. Further, the lack of reliable information impairs the government's ability to (1) know the quantity, location, condition, and value of assets it owns, (2) safeguard its assets from physical deterioration, theft, loss, or mismanagement, (3) prevent unnecessary storage and maintenance costs or purchase of assets already on hand, and (4) determine the full costs of government programs that use these assets. Consequently, the risk is high that the Congress, managers of federal agencies, and other decision makers are not receiving accurate information for making informed decisions about future funding, oversight of federal programs involving inventory, and operational readiness.[117]

Given these challenges, the DOD prescribes many directives and instructions within their strategy, establishing standards that must be followed; this overall process involves item unique identification data (IUID) and Unique Item Identifiers (UII).

To improve fiscal responsibility, the DOD has mandated IUID to enable lifecycle management and visibility, management, and accountability of assets. DOD Directive 8320.03, "Unique Identification (UID) Standards for a Net-Centric Department of Defense" establishes policy and prescribes the criteria and responsibilities for creation, maintenance, and dissemination of UID data.[118] DOD Instruction (DODI) 8320.04 "Item Unique Identification (IUID) Standards for Tangible Personal Property, is the document that covers policy implementation.[119] Other DODIs require accountability records to be established for all Government property with a unit cost of $5,000 or more, in addition to items that are sensitive or classified, regardless of cost, and these accountability records must provide a complete record of all transactions that will pass an audit.[120] The document spells out in a detailed manner, which items and how to uniquely identify them, which delves into a complex technical programming language for these codes. The DOD recognizes several commercial IUID equivalents:

1. Global Individual Asset Identifier (GIAI) for serially-manage assets.
2. Global Returnable Asset Identifier (GRAI) for returnable assets which shall contain a unique serial number for DOD IUID equivalent application. Other variations of the GRAI are unacceptable.
3. ISO Vehicle Identification Number (VIN) for vehicles.
4. Electronic Serial Number (ESN) (for cellular telephones only).
5. Cellular Mobile Telephone Identifier (CMTI) (for cellular telephones only).[121]

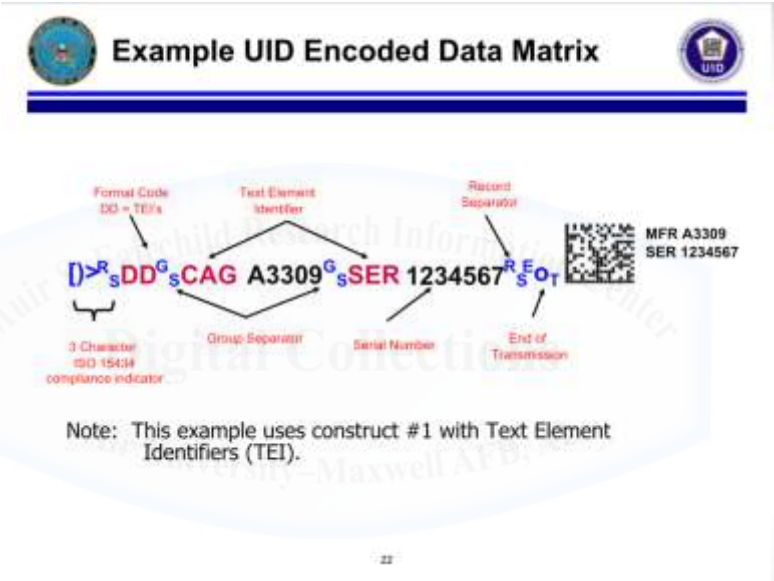

Figure 3. Example UID Encoded Data Matrix.[122]

A commercial identifier is considered for inclusion into the list of officially recognized DOD IUID equivalents if it meets the following criteria: contains an enterprise identifier, uniquely identifies an individual item within an enterprise identifier, product, part, lot, or batch number, and has either an existing Data Identifier (DI) or Application Identifier (AI) in accordance with the ANS MH10.8.2, Data Identifier and Application Identifier Standard, as well as complying with established Business Rules. The process of UII and creating the actual code

for an item is a task suited for a programmer, that can understand all the items of a 50-character code, guided by in-depth standards and guides to accomplish.

Department of Defense Suppliers' Passive RFID Information Guide

The DOD provides detailed information to its suppliers with respect to RFID protocol. The Office of the Assistant Secretary of Defense for Sustainment has an RFID homepage on the internet, supplying information and answers to frequently asked questions for suppliers. The Under Secretary of Defense for Acquisition, Technology & Logistics also publishes an information Guide for suppliers. RFID requirements are independent of UID requirements according to the DOD. Existing UID requirements remain in place regardless of whether or not there is an RFID requirement.[123] The IUID initiative by the DOD involves "assigning a globally unique, unambiguous data set to identify tangible assets to ensure data integrity and quality throughout the life of the product."[124] Where the UID becomes a permanent attachment or embedment to an asset, a passive RFID tag is applied to the package for the purpose of asset visibility while in transit, in storage, in use, or in maintenance.[125] Current CONOPS dictate that UID is the primary automated identification technology (AIT) for single item identification, whereas RFID is the primary AIT when items are consolidated and packaged above the item level.[126]

Figure 4. Example UID Labels.[127]

The DOD's goal is to employ RFID technology to facilitate automated visibility and assessment management.[128] To achieve this goal, the DOD requires cooperation from its suppliers, requiring them to affix passive RFID tags to consolidated and packaged shipments above the item level, in accordance with the Defense Federal Acquisition Regulations Supplement (DFARS).[129] The DOD states within the document that it will continue to update the guide as technology and business processes evolve. Highlighted benefits to a DOD supplier are stated as improved planning, faster demand responses, reduced Bull Whip effect, streamlined business processes, improved efficiency in the recall of defective items, increases the ability to ensure that product(s) remain stocked on DOD's shelves, and faster receipt of payment for supplied goods.[130] Benefits to the DOD include improved inventory management, improved labor productivity, elimination of duplicate orders, replacement of manual procedures, automated receipt and acceptance, improved inventory and shipment visibility and management, reduced shrinkage, enhanced business processes within the DOD, and improved asset tracking.[131]

ANALYSIS, RECCOMENDATIONS, AND CONCLUSION

Analysis

Radio Frequency Identification has come a long way since its advent in World War II aircraft identification compared to the high-tech tags and readers available on the market today that can serve a multitude of complex purposes. Certainly, the advancements in RFID technology and its lower cost of entry over the last fifteen years lend themselves to the idea that implementation of this technology Air Force-wide should be a feasible endeavor, but the research presents solid reasons why that is not the case. Although a myriad of examples in the commercial industry prove how this technology can be leveraged to improve efficiency, safety, and costs, trying to apply the same products and process on an Air Force-wide scale is simply not feasible. As Mr. Morgan, at Headquarters Air Force stated, Air Force logistics and supply chains dwarf any commercial industry comparison by orders of magnitude. Because of the size of the Air Force and its operations, a service wide implementation of RFID technology is not feasible. The key points of comparison between the commercial sector and the Air Force are not only the scale differences, but also the barriers to implementation associated with DOD acquisition and implementation, especially when discussing technology. First, the budgetary constraints faced by the Air Force when compared to the commercial, for-profit industry, are drastically different. Second, the ability to implement new technology in an effective timetable within the DOD pales in comparison to the commercial sector, which explains why new technology is not implemented at the same rate in the Air Force. Although there are advantages to implementing RFID technology, there are many more barriers to that entry than simply cost alone, a fact that Mr. Morgan detailed to RFID industry leaders in his speech at the RFID Journal LIVE! Conference.

Given the detailed analysis of the Air Force's current state of RFID technology implementation by Mr. Morgan, it is tough to be overly critical of the suspected failure of the AFGET that was implemented at Robins Air Force base. Ultimately, AFGET should absolutely be praised for the progress that was made over fifteen years with their tracking system. Although painfully slow, it is the model for a large-scale program that can be implemented Air-Force wide, given enough time and money. The biggest lesson however, is that despite there only being isolated examples of successful case studies within the Air Force, the DOD at large is fully committed to harnessing this technology. This is seen with the fourth iteration of the RFID Indefinite Delivery Indefinite Quantity contract won by Savi Technology Inc. earning them an award of $102 million. Being the sole provider within this contract, the DOD has established a relationship with Savi over two decades that proves this technology can be adapted for use effectively within the DOD.

Recommendations

Given the complexities of implementing an RFID technical solution at the Air Force level, this research concludes that it is not a feasible option for any large-scale action and recommends against an attempt at such a feat at the present time. This conclusion draws upon the expertise of the Engineering and Force Protection, IT Integration Branch Chief for the Air Force, Mr. Morgan and his in-depth understanding of the constraints faced by the Air Force when compared to the private sector. Certainly, there are examples of technology being implemented Air Force and even DOD-wide, such as the Common Access Card (military ID), but such examples serve a limited use. The Common Access Card stores a limited amount of information on an integrated circuit chip, that serves a limited number of purposes, such as Public Key Infrastructure certificates for signing, encrypting, and decrypting emails. Despite a

small number of examples that might be found within the Air Force with respect to implementing a technological solution, a technology such as RFID, which can serve many detailed purposes, across a wide range of tasks, is too cumbersome to achieve.

It is important to note however, that RFID technology is more prominent within the DOD and the Air Force than might be suspected or known. Considering that there are DOD instructions governing its use, and even requiring its use by vendors in the supply chain, it proves that there is a commitment from the DOD to continue to pursue the technology, even if the burden may be placed more on entities outside of the organization at this time. Although DOD requirements may be strict with regard to vendor business and shipping transactions, there is plenty of leeway for the Air Force to harness the advantages of this technology.

This research provided several case studies of success in implementing RFID technology, from the small scale seen at Stadium where inventory accuracy improved from 65 percent to 97 percent, or within BAE Systems and Boeing where over $100 million in savings were realized. A perfect example of harnessing this technology on a small scale was seen with the inspection for life support equipment aboard aircraft by Boeing. For RFID technology to proliferate within the Air Force, it is incumbent upon the individual units to explore the technology, utilizing their discretionary budget to implement, in order to improve cost, efficiency, and safety in the individual unit. These small-scale experiments, perfected over time, may be well suited to spread Air Force-wide within their realm of responsibility. Although RFID technology may be prolific within the commercial industry, it simply is not a readily accessible technology within Air Force units today.

Provided that RFID technology does not see wide spread usage within the Air Force, perhaps due to lack of understanding of its benefits, or how to implement it, this research

recommends that an RFID Common Operational Picture (COP) be established on the Air Force Portal for individual units to access and share with each other their successes and failures along with recommendations, policies, and products used. Establishing a forum to share ideas, success, and failures, will allow the use of RFID technology to grow within the Air Force. Eventually, as these ideas proliferate, Headquarters Air Force may deem these applications both beneficial and feasible to implement on an Air Force-wide scale. Just as AFGET paved the way for other sustainment centers' adoption of this technology so might other small units in the Air Force.

The Air Force has a history of creating programs to harness innovation. Examples of this are things such as the "Idea" website, where Airmen can offer ideas on how to revitalize Air Force squadrons, or the Airmen Powered by Innovation which replaced three separate "good idea" programs. Another recent program was the Air Force "Spark Tank" that awards funding and senior leadership support to Airmen to move forward with their ideas. These are all great ways for individuals within units to investigate the benefits of RFID technology and pursue it further. Awards for funding RFID technology should be investigated for sourcing from the RFID-IV contract, with the assistance of Savi's expertise, as the trusted DOD contractor.

The Air Force must continue to leverage the commercial industry advancements in RFID technology, even if implementation may be on a smaller scale and slower timeline. A key way to do this is to continue to be involved in the industry, by attending events such as the RFID Journal LIVE! Conferences held each year. Through attendance, Air Force officials will be able to both observe current trends and advancements in the private sector, as well as convey the Air Force's needs to industry leaders, where eventually the two paths will cross and result in solutions that will improve efficiency, cost, and safety, on both small and large scales within the Air Force.

Conclusion

In conclusion, Radio Frequency Identification is a rapidly advancing technology that can solve multiple problems with a single integrated solution. There are however, more barriers to entry within the Air Force than cost alone. The DOD is committed to adapting this technology to enhance efficiency, cost, and safety, however it is simply not feasible to implement on an Air Force-wide scale at this time, given the complexity and size of the enterprise. Units within the Air Force should seek out ways to adapt this technology within their individual units, and share their successes and failures across the Air Force so that others may build upon their experience. This growth of corporate knowledge within the Air Force at the unit level, will result in a robust network of ideas and solutions that may provide Air Force-wide solutions to implementation in the future.

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