NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

A METHODOLOGICAL APPROACH FOR CONDUCTING A BUSINESS CASE ANALYSIS FOR THE ADVANCED TECHNOLOGY ORDNANCE SURVEILLANCE (ATOS) ADVANCED CONCEPT TECHNOLOGY DEMONSTRATION (ACTD)

by

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December 2005

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The purpose of this thesis is to provide a methodological approach for conducting a Business Case Analysis (BCA) for the Advanced Technology Ordnance Surveillance (ATOS) Advanced Concept Technology Demonstration (ACTD). This study compares the cost savings over time of having an ATOS infrastructure in place at Navy Munitions Management locations compared to the base case of "as-is" inventory management.

ATOS is a Radio Frequency Identification (RFID)-based automated system that provides a capability to collect environmental data in near real-time and supports munitions management tasks on stored munitions pallets. This type of data has never before being available and is critical for making more precise decisions about the shelf life and operational performance of individual munitions throughout their service life. ATOS is not meant to be a replacement for the status quo processes of Ordnance Management (OM). Instead, ATOS is meant to enhance many of the current processes and add additional capabilities and dimensions to OM.

A Business Case Analysis for a notional site, using exemplar data sets indicates that with an initial investment of $1.3M, a Net Present Value (NPV) of $5.3M can be obtained over a 10-year period. The payback period is less than one year, and the Return on Investment is 214 %, or almost 11 % annual, compounded ROI.

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A METHODOLOGICAL APPROACH FOR CONDUCTING A BUSINESS CASE ANALYSIS FOR THE ADVANCED TECHNOLOGY ORDNANCE SURVEILLANCE (ATOS) ADVANCED CONCEPT TECHNOLOGY DEMONSTRATION (ACTD)

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LIST OF ACRONYMS AND ABBREVIATIONS

ACTD	Advanced Concept Technology Demonstration
ADC	Automatic Data Collection
AD&C	Ammunition Distribution & Control
AFOTEC	Air Force Operational Test and Evaluation Center
AIS	Automated Information System
AIT	Automated Identification Technologies
AMC	Air Mobility Command
AS&C	Advanced Systems and Concepts
AT&L	Acquisition, Technology and Logistics
ATOS	Advanced Technology Ordnance Surveillance
BCA	Business Case Analysis
BOE	Basis of Estimate
CE	Cost Estimate
COCOM	Component Commander
COTS	Commercial Off-the-Shelf
DOD	Department of Defense
DODIC	Department of Defense Identification Code
DUSD	Deputy Under Secretary of Defense
EDB	Environmental Database
EMD	Engineering Manufacturing and Development
EPC	Electronic Product Code
GPS	Global Positioning System
HHR	Handheld Reader
ID	Identification
JROC	Joint Requirements Oversight Council
JWCA	Joint Warfare Capability Assessment
LAN	Local Area Network
LRIP	Low-Rate Initial Production
LTA	Logistics Transformation Agency
MBA	Master of Business Administration
MEMS	Micro-Electromechanical Systems
MUA	Military Utility Assessment

NDI	Non-Developmental Item
NOSSA	Naval Ordnance Safety and Security Activity
NPS	Naval Postgraduate School
NPV	Net Present Value
NSN	National Stock Number
NSWC	Naval Surface Warfare Center
OM	Ordnance Management
O&S	Operation & Support
OSD	Office of Secretary of Defense
PEO	Program Executive Officer
PM	Program Manager
PP	Pre-Processor
QE	Quality Evaluation
RCU	Reader Control Unit
RF	Radio Frequency
RFE	Radio Frequency Extender
RFID	Radio Frequency Identification
RH	Relative Humidity
ROI	Return on Investment
RSS&I	Receipt, Segregation, Storage, & Issue
SME	Subject Matter Expert
UHF	Ultra High Frequency
USD	Under Secretary of Defense
USTRANSCOM	United States Transportation Command
WBS	Work Breakdown Structure
WBSE	Work Breakdown Structure Element
WLAN	Wireless Local Area Network

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Most importantly, I would like to thank my family, Mom, Dad, and Liza. Without their love and support none of this would have been possible. Thank you.

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EXECUTIVE SUMMARY

The purpose of this thesis is to provide a methodological approach for conducting a Business Case Analysis (BCA) for the Advanced Technology Ordnance Surveillance (ATOS) Advanced Concept Technology Demonstration (ACTD). This study provides a methodology for comparing the cost savings over time of having an ATOS infrastructure in place at Navy Munitions Management locations compared to the base case of "as-is" inventory management.

ATOS is a Radio Frequency Identification (RFID)-based automated system that

- Provides a capability to collect environmental data in near real-time, and
- Supports munitions management tasks on stored munitions pallets.

These types of data have never before being available and are critical for Ordnance Mangers and warfighters in making more precise predictions about the shelf life and operational performance of individual munitions throughout their service life. ATOS is not meant to be a replacement for the status quo processes of Ordnance Management (OM). Instead, ATOS is meant to enhance many of the current processes and add additional capabilities and dimensions to OM.

With the assistance of Subject Matter Experts (SMEs) from Naval Surface Warfare Center (NSWC), Indian Head Division, a Work Breakdown Structure (WBS) with Cost Estimates (CEs) for the implementation of an ATOS infrastructure was generated. These cost estimates were used in calculations to determine the "as-is" and the "to-be" inventory costs. These costs were used in a Business Case Analysis to determine the potential cost savings and benefits of implementing an ATOS infrastructure at a notional, five magazine munitions site, which is meant to be analogous to Navy Munitions Management locations.

This Business Case Analysis methodology only provides cost savings for this notional base case. In order to provide realistic cost savings with a greater degree of accuracy, a pilot program has been scheduled for later this year to assess further the benefits, including cost impacts, of the ATOS technology.

A Business Case Analysis for a notional site, using exemplar data sets indicates that with an initial investment of $1.3M, a Net Present Value (NPV) of $5.3M can be obtained over a 10-year period. The payback period is less than one year, and the Return on Investment is 214 %, or almost 11 % annual, compounded ROI.

To validate the cost estimates used, a full scale ATOS pilot project at a munitions location, such as, Seal Beach, needs to be funded and implemented in order to collect the required data to validate the results from previous analysis, and support and provide a better argument as to why ATOS is the way to go in Ordnance Management.

Additionally, in order to establish an ATOS implementation plan DoD wide, a study on optimizing the placement of ATOS needs to be initiated. The optimization will account for both where ATOS should be implemented, as well as a time phased approach to the implementation. These analyses will help decision makers in determining the optimal locations that provide the greatest savings due to the large munitions stockpiles. For example, small munitions facilities where munitions do not have a high cycle rate may not be a high priority for the implementation of ATOS.

Finally, the RFID tags chosen to be attached to munitions pallets need the capability to collect the environmental data that is required by QE personnel to input into models to provide Ordnance Managers valuable information about the status of their munitions in inventory.

I. INTRODUCTION

A. PURPOSE OF THIS STUDY

The purpose of this thesis is to analyze the potential cost savings and benefits associated with the implementation of an Advanced Technology Ordnance Surveillance (ATOS) infrastructure at Navy Munitions Management locations. ATOS will provide ordnance managers the ability, on a near real-time basis, to locate accurately and to determine continuously the environmental status of high value, low density munitions on a near real-time basis while also updating predictions of the future condition and performance of the ordnance. In the future, a Navy Munitions Management location will be selected to initiate a pilot program to assess and validate the benefits of the technology. This study provides a methodology for comparing the cost savings over time of having an ATOS infrastructure in place compared to the base case of "as-is" inventory management.

ATOS was chosen for this thesis for two reasons:

- Importance to the Deputy Under Secretary of Defense (DUSD) due to its high visibility in the DOD RFID policy.
- Example of the process by which a project transitions from an Advanced Concept Technology Demonstration (ACTD) in technology base to a program of record in the DOD 5000 Acquisition System.

1. Potential Cost Savings and Benefits

The promise of an ATOS infrastructure for the ordnance manager is that it can provide continuous, comprehensive, and real-time visibility of current inventories. Real-time visibility enables ordnance managers and ammunition site managers to avail themselves of the following potential benefits:

- Reduce inventories using more accurate data about supply and demand of ordnance.
- Reduce out-of-stocks based on minimum thresholds

- Provide a foundation for event-driven optimization to enable the re-optimization of the supply chain logistics when a problem occurs, e.g., an airplane carrying munitions to the theater breaks down.
- Reduce manual inventory management tasks, thereby reducing human errors and freeing up labor to be reallocated to more mission-critical activities
- Identify and reduce shrinkage across the munitions supply chain
- Improve efficiencies within munitions warehouses by reducing time spent searching for specific items
- Improve asset management and more accurately validate physical inventory with accounting data
- Improve responsiveness to munitions recalls through greater specificity, which will pinpoint exactly which lots of items need to be returned and where to find them
- Maintain or extend munitions shelf life due to timely preventive maintenance or calibration
- Avoid having to replenish stolen or misplaced items since an RFID tag can be integrated to an alarm system

B. WHAT IS RFID?

Radio Frequency Identification is an Automatic Data Collection (ADC) technology that uses radio frequency waves to transfer data between an RFID reader and an item of interest to which an RFID device (tag) is attached in order to identify it, categorize it, and track it. Compared to the "as-is" inventory management system, RFID can greatly reduce the time to conduct an inventory because it is fast, reliable, and does not require line of sight or contact between the RFID reader and the RFID tagged item. This non-line of sight physical characteristic means that tags can be read through a variety of RF propagation media, to include fog, snow, dirt, grime, and other visually and environmentally challenging conditions. In these conditions, barcodes or other optically read technologies would be useless.

Present technology allows RFID tags to be read at very high speeds, even in adverse weather conditions responding in less than 100 milliseconds [SAVI 2005]. Due to its capability and reliability, RFID technology has been adopted in a wide range of automated data collection and identification applications that would not be possible otherwise.

1. RFID Characteristics

There are six important characteristics of RFID that impact the transfer of data between a tag and an RFID reader: range, range adjustment, propagation, directionality, multi-tag collection, and memory [SAVI 2005].

a. Range. Range is defined as the maximum distance for a successful communication between the RFID tag and RFID reader. RFID technology allows RFID readers to communicate successfully with RFID tags in either of the following ranges:

- Very short range: Up to 60 centimeters (two feet)
- Short range: Up to five meters (16 feet)
- Long range: Greater than 100 meters (320 feet)

Frequency is one of the leading factors that effects range of a successful tag-reader communication and determines the type of RFID technology that should be used for a specific implementation. Low frequency systems have short reading range and are most commonly used in item tracking and security access implementations. High frequency systems offer long read ranges and high reading rate and are commonly used for railroad car tracking and automated toll collection. Table 1 below displays common RFID frequencies being used in RFID readers.

Frequency Band	Description	Range
125 – 134 KHz	Low frequency	To 18 inches
13.553 – 13.567 MHz	High frequency	3 -10 feet
400 – 1000 MHz	Ultra-high frequency (UHF)	10 - 30 feet
2.45 GHz	Microwave	10+ feet

Table 1. Common RFID Frequencies and Passive Ranges (From Ref. Intermec Technologies Corporation 2004).

b. Range adjustment. Range adjustment is the RFID reader's ability to automatically adjust the range at which it is being operated. Tag reader communication is guaranteed within the specified range of the reader and tag-reader communication outside the specified range is impossible.

c. Propagation. Propagation is the ability of the RFID reader to perform tag-reader communication through or around objects and material. With very good propagation, the RF can penetrate through items allowing successful data transfer between the tag and reader. Having good propagation enhances the penetration through water, liquids or human tissue.

d. Directionality. Directionality is the ability of the RFID reader to achieve directional RF coverage using directional antennas. There are two types of directionality: Omni-directional and Directional. Omni-directional coverage has the same RF intensity (or coverage) in all directions. With directional coverage, the RF intensity is much stronger in one specific direction.

e. Multi-tag collection. Multi-tag collection is the ability of the RFID reader to process more than one tag within a designated area.

f. Memory. Tags range from small memory size (16 bits) to large memory (at least 512 kilobytes). Memory is an important characteristic in RFID communication because it determines the read only (passive RFID), read/write (active RFID), or write-once-read-many capabilities in the tag-reader communication.

C. HOW DOES AN RFID SYSTEM WORK?

Figure 1 shows a typical RFID configuration, consisting of

- one or more RFID tags,
- two or more antennas,
- one or more interrogators,
- one or more host computers, and
- the appropriate software to transform the raw data into useable information.

In a basic RFID tag operation, radio waves are used to transfer data between the RFID tag (transponder) and the read/write device (interrogator), which is tuned to the same frequency. The interrogator sends out a signal, which is received by all tags that are present in the radio frequency (RF) field tuned to that frequency. Tags that receive the signal respond by transmitting their stored data. The tags can hold many types of data about the item, such as its serial number, configuration instructions, what time the item traveled through a certain zone, temperature and other data provided by sensors.

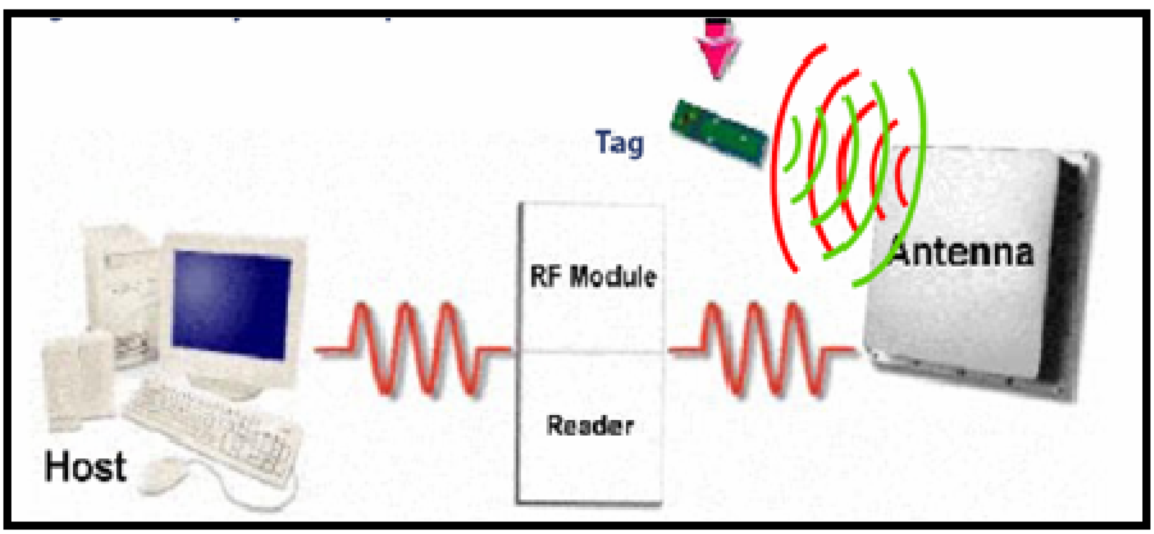

Figure 1. RFID System Components (From Ref. Intermec Technologies Corporation 2004).

The read/write device receives the tag signal, decodes it and transfers the data to the host computer system.

RFID tags can be attached to virtually anything – from an airplane, to a pallet, to a case, to an item stored on a shelf. If multiple tags are present in the field of interrogation, more efficient RFID implementations have anti-collision algorithms, which determine the order of response so that each tag is read once and only once.

D. ACTIVE RFID TAGS

The term "active" means that there is an internal battery source installed in the tag to provide power to send a signal on demand. Active RFID tags are wireless transponders which can automatically identify, locate, track, monitor, and protect a variety of items of interest. Unlike Global Positioning System (GPS) which is available worldwide, active RFID only operates around the operation site where the RFID infrastructure has been implemented. Active tags can be activated for transmitting when they reach a particular location, or, they can be programmed to transmit at set intervals, or when a change of condition occurs. Changed conditions include movement or sensor thresholds such as temperature, humidity, shock or any number of sensor detections.

Active tags, because of their power source, also have the ability to act without an external activation, thereby providing a number of added value functions. For example:

- A tag can be configured to alarm and send an alert signal if the tag is removed, so (anti-tamper) active tags provide a security solution for assets and containers.
- Tags equipped with a motion sensor can alarm in the event of unauthorized inventory movement.
- Beaconing tags can provide an automatic inventory count. Beacon tags send signals to a receiver at pre-determined time intervals to provide continuous monitoring on the inventory and its location.

1. Active RFID Key Capabilities

In an August 2004 market study and end user survey by Venture Development Corporation [Axcess 2005], active RFID systems, compared to the passive RFID inventory management systems (i.e., non-active RFID systems) were found to have a series of valuable characteristics, including the following:

- Enhanced dependability because of high performance, i.e., active RFID is continuously emitting RF energy, thereby, providing the user with the latest information
- Enhanced security/access control including theft reduction
- Provided the ability to link tags together in software for custodianship
- Provided the ability to automate identification and location by removing human intervention
- Improved the accuracy and reliability of data
- Improved read accuracy and longer read ranges than passive RFID
- Increased data transfer rate

E. PASSIVE RFID TAGS

Unlike active tags, passive RFID tags do not have an internal battery source. Passive RFID tags rely on capturing and re-using a small portion of the wake-up signal's energy to transmit its RFID tag ID and other information back to the receiver. This requires a strong RF signal from a reader and limited available energy constrains the RF signal strength returned from the tag. For this reason, passive RFID tags can only operate over very short ranges and requires a line of sight for successful operation. This is a "good news, bad news" situation [Axcess 2005]. The "good news" is that passive tags can be manufactured and sold at much lower prices than active tags because of their capability. This can be a critical decision point in many RFID supply chain applications requiring literally millions of tags. The "bad news" is that passive tags are not 100% reliable because they depend on a small amount of power to push their signal off metal surfaces or through layers of palletized items.

In short, active tags therefore have an innate performance advantage over passive tags when it comes to providing a consistently robust, penetrating signal. When activated, active RFID tags send a signal capable of being read at much greater ranges than passive RFID tags.

F. DEPARTMENT OF DEFENSE (DOD) RFID POLICY

Mr. Michael Wynne, Acting Under Secretary of Defense (USD) (Acquisition, Technology and Logistics (AT&L)), announced a new RFID policy on July 30, 2004 within the DoD [USD 2004]. The DoD requires passive RFID tags on the case, pallet, and item packaging for Class I (subsistence and comfort items), Class II (clothing, individual equipment, and tools), Class VI (personal demand items), and Class IX (weapon systems repair parts and components) commodities delivered on or after January 1, 2005. For about two years, DoD will accept Electronic Product Code (EPC) Class 0 (read only) or Class 1 (read/write) passive RFID tags. DoD will migrate to Ultra High Frequency (UHF) Generation 2 tags when specification is finalized. In accordance with a white paper [Alien Technology Corporation 2005], these Generation 2 tags will be the tags of the future. It is expected that Generation 2 tags will have the capability to read over 1,000 tags per second.

The following excerpts were taken from a November 12, 2005 article in New York Times, titled "Military To Urge Suppliers To Adopt Radio ID Tags," reported that the Defense Department will begin prodding suppliers to use RFID tags on cartons and pallets or goods entering DoD's vast supply system.

> Further paving the way for a type of inventory tracking technology that Wal-Mart is already turning into a commercial standard, the Defense Department on Monday will begin prodding suppliers to use radio-frequency ID tags on cartons and pallets of goods entering its vast supply system.
>
> The tags, meant to let goods be tracked without the proximity and line of sight required by bar-code scanners, have vast potential for military, homeland security and commercial applications. But just as Wal-Mart is proceeding in steps, starting only with its biggest suppliers, so will the military adopt the radio tags in stages.

The new program will initially apply only to a range of combat-support goods handled by the Defense Department's two largest supply centers: the Susquehanna depot in New Cumberland, Pa., and the San Joaquin depot in Stockton, Calif. And rather than adding the requirement to existing contracts, the military will make it a proviso of new or renewed contracts.

But some of the Defense Department's largest suppliers say they will tag some goods headed to Susquehanna and San Joaquin even before new contracts require them to do so.

It's a critical part of our effort to support the war fighter and we want to be an industry leader, said George Ellis, who oversees radio-frequency ID at Raytheon, which has also been testing use of the tags to track goods inside its own operations.

While giants like Raytheon are handling the tagging of military goods themselves, many smaller companies are using outside contractors like SimplyRFID, a four-year-old consulting and management company based in Warrenton, Va.

"Our traffic is up significantly in the past two weeks," said Carl Brown, president of SimplyRFID, which charges customers shipping 5,000 items or less to the military roughly $1 a tag.

Alan Estevez, the Defense Department logistics policy specialist who is overseeing the program, emphasized the gradual phase-in of the technology. "I'm not expecting a Big Bang on Nov. 14," he said.

Even so, tens of thousands of the Defense Department's estimated 60,000 suppliers could come under its requirements within a year, Mr. Estevez said. The program calls for adding another 34 supply centers next year and the rest of the military's distribution operations in 2007.

Supporters of the tagging technology said that the military's new rules were the biggest step forward for radio tags since Wal-Mart Stores began requiring its largest suppliers to use them for shipments to three distribution centers last January. Wal-Mart, which also supported the tagging at 150 stores served by the distribution centers, has since expanded its program to more distribution centers and 500 stores, with plans to double that number early next year.

In theory, the tagging will eventually wring billions of dollars in waste out of supply chains, sharply curtail theft and counterfeiting, and reduce the frequency of shoppers' encountering empty shelves instead of the products they want. The tagging may also speed customers through checkout lanes because, unlike bar-code scanners, tag readers can look for numerous products with a single signal.

In practice, though, figuring out where to place the readers and the tags to get data reliably has proved to be an expensive trial-and-error process. Compared with the military supply chain, Wal-Mart's distribution system is in some ways more difficult to manage than the Defense Department's because goods move through the Wal-Mart consumer pipeline so much more rapidly. But the military has far more suppliers, along with a complex mix of new, replacement and repaired goods, and less predictable demands than Wal-Mart's seasonal peaks.

What is more, "the backroom of a Wal-Mart on a Saturday afternoon may be hectic, but it's not like a mobile supply center in the desert that's being shot at," Mr. Estevez said. The military's backing gives other users and investors confidence in radio tags, said Kevin Ashton, vice president of ThingMagic, a manufacturer of tag-reading devices based in Cambridge, Mass. "You have to give people the sense that this is inevitable to have the opportunity to work out the details," he said.

The details have been a challenge. The Defense Department and private-sector trucking and shipping companies have plenty of experience with battery-powered tags able to communicate with satellites to track large containers and expensive equipment.

The microchips in the tags now being introduced by the military and Wal-Mart, however, rely on power emitted from the scanners to provide the energy the tags need to respond. Plans call for applying these "passive" tags to billions of items before the end of the decade.

Researchers at the University of Arkansas reported last month that 12 Wal-Mart stores with radio tag scanners in their storerooms were able to restock shelves at three times the speed of a control group of 12 stores that relied on traditional methods to locate stock. The tag stores were 16 percent less likely to have empty shelves.

Wal-Mart hailed the study as proof of the technology's value. But it did not quantify the actual savings. And AMR Research, a consulting company, concluded from a survey of major Wal-Mart suppliers that it would take them more than nine years to earn a payback on their investments at current tag and reader prices - far beyond the one-to-two-year time horizon that would make the technology financially attractive.

The military may encounter far less resistance. Unlike Wal-Mart, the government expects to shoulder the extra costs the technology imposes on suppliers. And the military's goals seem less likely to stir up opposition from privacy advocates who are opposing use of the tags in commerce.

"The real payback for D.O.D. is to have the soldier on the ground have the part needed to make a tank run or a plane fly," said Mr. Estevez.

G. PREVIOUS RFID WORK DONE AT THE NAVAL POSTGRADUATE SCHOOL (NPS)

There have been four Master of Business Administration (MBA) professional reports completed at NPS that researched different approaches to the employment of RFID within the United States military.

The first two projects considered the impact of active RFID in the supply logistics chain. There is a current focus on supply logistics chain activities, as part of several DoD initiatives to provide total product visibility of all cargo movements in support of the troops.

The third study conducted a cost-benefit analysis of implementing an active RFID infrastructure as a real-time asset management tool within a military hospital.

The fourth thesis conducted an analysis of cost and benefits associated with the implementation of an active RFID infrastructure at a maintenance depot. These theses are summarized below.

1. USTRANSCOM and In-transit Visibility

This NPS thesis was completed in December 2003 [Hozven 2003] and focused on the Air Mobility Command (AMC), an organization under the United States Transportation Command (USTRANSCOM) which is accountable for all military transportation and is responsible for establishing the global RFID infrastructure. The primary objective of this study was to assess the potential value of RFID to AMC if used in its worldwide network of ports to manage the supply logistics chain. The study concludes that there are benefits to using RFID but more pilot projects are needed to be implemented to fully quantify the value of RFID technology. This thesis in PDF format can be accessed at the following link:

http://stinet.dtic.mil/cgi-bin/GetTRDoc?AD=ADA420561&Location=U2&doc=GetTRDoc.pdf

2. Value of Supply Chain Logistics Information

This NPS thesis was completed in June 2004 [Corrigan 2004] and attempts to quantify the value added by using RFID. It does this by investigating what a Supply

Officer was willing to pay for real-time information and visibility of products in the supply logistics chain. The report concludes that real-time logistics information is valuable in order to effectively support the warfighter. Additionally, the thesis noted that RFID offers tangible cost savings to include reduction in labor costs, as well as intangible benefits of better access to information to allow for better management decisions concerning allocation of limited resources. This thesis can be accessed in PDF format at the following link:

http://stinet.dtic.mil/cgi-bin/GetTRDoc?AD=ADA424676&Location=U2&doc=GetTRDoc.pdf

3. Management of Medical Equipment

This NPS thesis was completed in December 2004 [Sánchez 2004], and its primary focus was to identify the value of RFID in the management of medical equipment at the Naval Medical Center in San Diego, California. The study concluded that the value of RFID was two fold:

- Cost savings produced by the elimination of replacement costs caused by lost equipment
- Increased efficiency in manpower utilization by avoiding the time required to find lost equipment.

The study presented a Return on Investment (ROI) analysis that illustrated a positive Net Present Value (NPV) in less than a year when RFID was implemented under the study conditions. This thesis can be accessed in PDF format at the following link:

http://stinet.dtic.mil/cgi-bin/GetTRDoc?AD=ADA429394&Location=U2&doc=GetTRDoc.pdf

4. Management of Equipment at Tobyhanna Army Maintenance Depot

This NPS thesis was completed in June 2005 [Miertschin 2005] and its purpose was to identify the potential value of RFID used for inventory and asset management at the Tobyhanna Army Maintenance Depot. This study concludes that RFID implementation proved beneficial to increase process efficiency and reduce the number of man-hours expended to find lost or misplaced equipment. This study "indicates a ROI of less than one year. This result supports other research conducted on RFID as an asset management tool, and indicates that Tobyhanna's investment in advancing technology essentially paid for itself within one year when measured in labor cost savings. More importantly, the technology yields an annual savings of 837 RCT days. Although we could theoretically assign a monetary value to the RCT savings, we believe the statistic adequately reflects the savings to the field." This thesis can be accessed in PDF format at the following link:

http://library.nps.navy.mil/uhtbin/hyperion/05Jun%5FMiertschin%5FMBA.pdf

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II. BACKGROUND

A. ADVANCED CONCEPT TECHNOLOGY DEMONSTRATION PROCESS

1. Introduction

Budget constraints, significant changes in threats, and an accelerated pace of technology development have challenged the ability of the Component Commanders (COCOMs) to adequately respond rapidly to the evolving military needs. Part of the Department of Defense response to thee challenges has been to initiate the Advanced Concept Technology Demonstration program in early 1994 to get new technologies into the hands of the warfighter as quickly as possible.

The ACTD program is designed to assist the DoD acquisition process adapt to today's economic and threat environments. ACTDs identify significant military needs and match them to mature technologies or technology demonstration programs which are maturing key technologies in order to solve important military needs (see Figure 2). These technologies are then combined and integrated into a complete military capability to provide decision makers an opportunity to understand fully the operational potential offered by a proposed new military capability before making an acquisition or sustainment decision. This goal is met by developing fieldable prototypes of the proposed capability and providing those prototypes to the warfighter for evaluation of that capability. The warfighter evaluates the capability in real military exercises and at a scale sufficient to assess fully military utility. During the ACTD, the warfighter also evolves the broad statement of need, which existed at the start of the ACTD, into a definitive set of operational requirements that can support a follow-on acquisition. At the completion of the ACTD, the prototypes used in the evaluation process are left with the warfighter to provide an interim capability or, in some cases, to fulfill the total, current need.

Figure 2 below displays the ACTD Development Process.

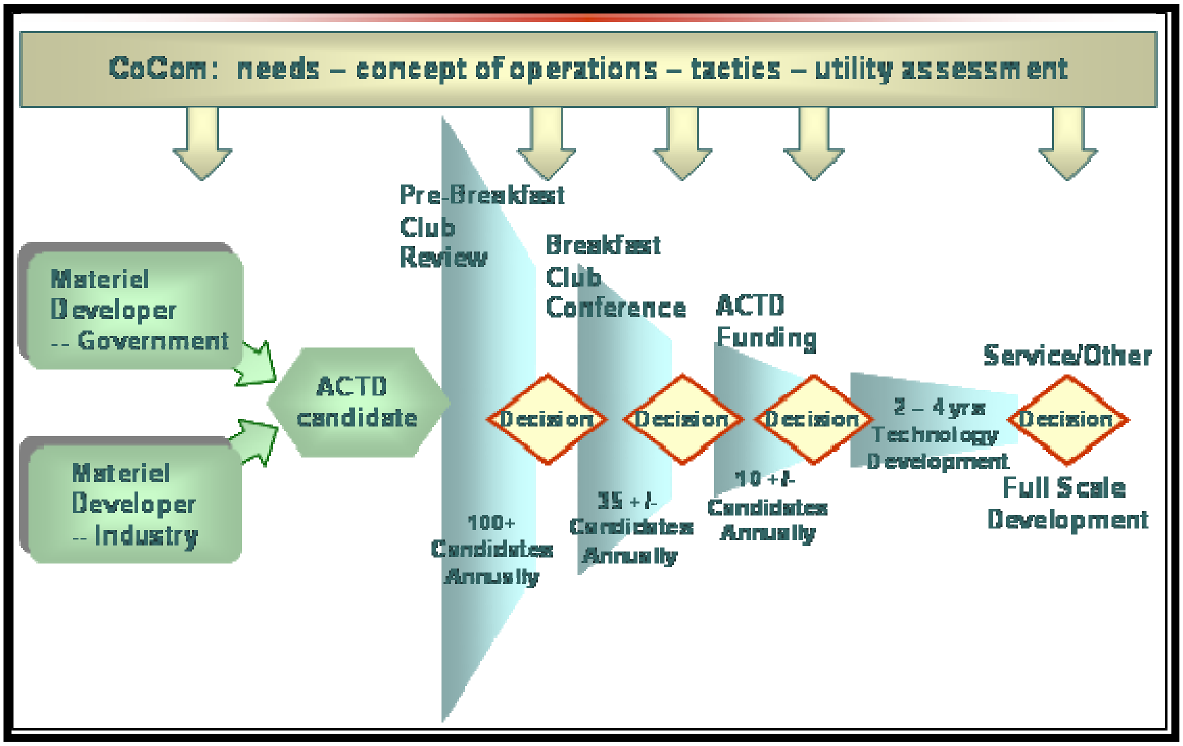

Figure 2. ACTD Development Process (From Ref. ACTD 2004).

In a February 24, 2005 article in Inside the Pentagon, titled "DOD Plans New Acquisition Executive Post To Champion Joint Programs," plans were announced on establishing the policies for ACTDs and JCTDs.

> The Pentagon plans to establish a new acquisition executive to champion technologies and concepts designed for joint operations, according to defense officials and documents.
>
> The creation of the new position is part of a wider effort to overhaul the advanced concept technology demonstration program -- the Pentagon's marquee project for rapidly fielding new technologies -- into another effort called the joint capability technology demonstration program.
>
> The goal is to expedite deliveries of new technologies to soldiers, sailors, airmen and Marines by putting in place new funding mechanisms and organizations to make sure new, proven weapons and combat technologies are designed for use by more than one service and not orphaned by individual services at budget time.
>
> Beginning Oct. 1, the Pentagon plans to have in place the new acquisition executive to ensure "cradle to grave" funding and advocacy for promising technologies that do not have clear champions in the Army, Navy, Air

Force or Marines. This new post would be equal in rank to the service acquisition executives, according to Defense Department officials.

To facilitate this undertaking the Office of the Secretary of Defense has shifted $40 million in its fiscal year 2006 budget proposal from the ACTD budget line to initiate JCTD programs.

"This is just seed money," said Mark Peterson, head of program resources and integration for the deputy under secretary of defense for advanced systems and concepts, in a Feb. 22 interview. "We expect in next year's budget that this might change."

So do senior Pentagon officials. In a late December budget decision, Deputy Defense Secretary Paul Wolfowitz directed the under secretary of defense for acquisition, technology and logistics and the chairman of the Joint Chiefs of Staff to establish an improved process to transition promising ACTDs to acquisition programs and bring forward a new spending proposal this summer for consideration in the FY-07 budget.

Pentagon officials say the joint capability technology demonstration effort is designed to deliver the improved transition process Wolfowitz seeks. It is the brainchild of Sue Payton, the deputy under secretary of defense for advanced systems and concepts, who has worked for the last 18 months to improve the ACTD process and put in place what she calls a new business model for rapidly fielding new technologies desired by combatant commanders.

Beginning in 1994, the ACTD program established an alternate route to quickly put new technologies in the hands of warfighters. The program takes new but relatively mature technology and offers the services the opportunity to assess prototypes in a military environment. Targeted to address pressing requirements, ACTDs typically spend three to four years in development, after which a handful of prototypes are delivered to military units. They spend as many as two more years evaluating the technology for operational usefulness.

This four- to six-year cycle is faster than the traditional acquisition cycle, which can take between 10 and 15 years from the concept stage to fielding.

In some cases, technologies developed through ACTDs are used primarily by a single service. At the end of the demonstration, the service can buy more of the capability or walk away from the project. Many ACTDs, however, are designed expressly for commanders who are seeking to improve the coordination and operations of service-specific technologies that weren't designed to work together. In some cases, the objective is to acquire a technology none of the services provides.

Once an ACTD is complete, the four-star combatant commanders who sponsor them must depend on one of the services to acquire the technology and fund its operational use, although U.S. Special Operations Command has unique acquisition authority and is exempt from this rule. The services, however, do not always rank ACTDs desired by combatant commanders high in their procurement portfolios.

"Military services and defense agencies have been reluctant to fund acquisition of ACTD-proven technologies, especially those focusing on joint requirements, because of competing priorities," the Government Accountability Office said in a December 2002 report.

The Pentagon's FY-06 budget request includes $40 million to kick start a number of proposals aimed at correcting key difficulties that have surfaced in guiding new technologies from government and commercial laboratories to troops and into the Pentagon's acquisition and operations accounts.

These funds will be spread across four new program elements to fund JCTDs as well as a pilot program to establish a new defense acquisition executive.

This new position would share rank with the service acquisition executives and be the primary advocate in the budget process for joint capabilities that do not have a natural place in any of the service accounts.

Key to the new approach is a change in how projects are funded. In order to remain as responsive to the current needs of combatant commanders, the Pentagon keeps ACTDs out of its planning, programming and budget execution cycle, which involves a two-year delay between requesting and receiving funds.

"So every time an ACTD starts, if a service has not already been planning, you have to break [another] program" to find the money for the new project, said Peterson. The net effect: "We create an instant unfunded requirement," he said.

Under the JCTD approach, the Office of the Secretary of Defense will provide more funds at the beginning of a project, boosting its start-up contribution from 30 percent to at least 50 percent in order to reduce the pressure on the services to find money for the project outside of the budget cycle.

The JCTD process will set shorter time lines for demonstrating new concepts or technologies.

"We would like to make that quicker by at least a year," said Peterson.

> The JCTD strategy will requires a final demonstration in two to three years, faster than the three-year to four-year goals for most ACTDs. In the first year, JCTD officials will be required to deliver a preliminary capability.
>
> After that, they must be 50 percent complete by the end of the second year and wrap up in the third year. Payton also wants 80 percent of JCTDs to transition at least half of their products into a permanent place in the Pentagon's budget.

The following are some examples of FY06 ACTDs and JCTDs. These ACTD/JCTDs have the potential to support COCOM missions, whether or not they evolve into full-fledged programs of record. For a full list of ACTDs and JCTDs, refer to Appendix A and the following web link.

http://www.acq.osd.mil/actd/descript.htm

- Comprehensive Maritime Awareness (CMA) JCTD
- CHAMPION (Counter Intelligence-Human Intelligence Advanced Modernization Program/Intelligence Operations Now) JCTD
- Extended Space Sensors Architecture (ESSA)
- Joint Modular Intermodal Distribution System (JMIDS) JCTD
- Large Data JCTD
- Multi-service Advanced Sensors to Counter Obscured Targets (MASCOT)
- Joint Enable Theater Access (JETA)
- Event Management Framework (EMF)
- Node Management And Deployable Depot (NOMADD)
- Small UAV

At the conclusion of the ACTD operational demonstration, there are three possible outcomes.

- First, recommend acquisition of the technology.

- Second, if the capability or system does not demonstrate military utility, the project is terminated or returned to the technology base.
- Third, the warfighter's need is fully satisfied by the fielded prototype capability that remained onboard and there is no need to acquire additional units.

2. ACTD/JCTD Transition Process

Figure 3 below outlines possible paths which the ACTD in review might follow as it transitions to a program of record.

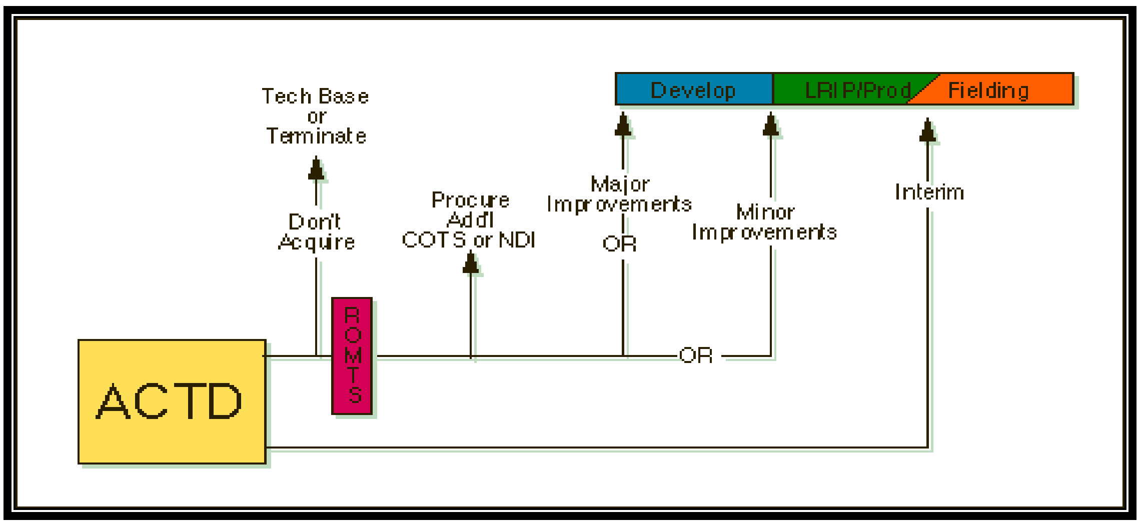

Figure 3. Alternatives Following Completion of ACTD (From Ref. ACTD 2004).

Transition to the formal Defense acquisition process will be necessary when development or production is required. The acquisition category will depend on both the number and cost of systems required to meet the military need. The next step is to determine at what point does the ACTD enters the acquisition process. If significantly more development of the technology is required, the system might enter into the development portion of the Engineering and Manufacturing Development (EMD) phase. On the other hand, if the capability of the ACTD is sufficient and needed promptly, entering into the Low-Rate Initial Production (LRIP) portion of EMD is an option.

There are three generic classes of ACTDs that present significantly different transition challenges (see Figure 4):

a. Class I ACTD. These are typically informational systems with special purpose software operating on commercial workstations. They frequently are required in small quantities, and that requirement can be satisfied without further development or production using the residual ACTD system (residual ACTD systems are the systems used during the ACTD that are left behind with the warfighter to meet his military need) or a few additional systems [ACTD 2004].

b. Class II ACTDs. These are weapon or sensor systems similar in concept to systems that are acquired through the formal acquisition process. In some cases a Class II ACTD will be planned ahead of time to transition into LRIP following ACTD, but at other times it is appropriate to plan for additional development following the ACTD [ACTD 2004].

c. Class III ACTDs. These ACTDs are best described as "systems of systems." This means that an individual element within the overall system of a Class III ACTD may be a fielded system, a system already in acquisition, or a system emerging from the technology base. The overall ACTD may involve multiple Program Executive Officers (PEO), and perhaps multiple Military Departments. The challenge here is to integrate and coordinate the individual transitions to achieve the capability presented in the ACTD [ACTD 2004].

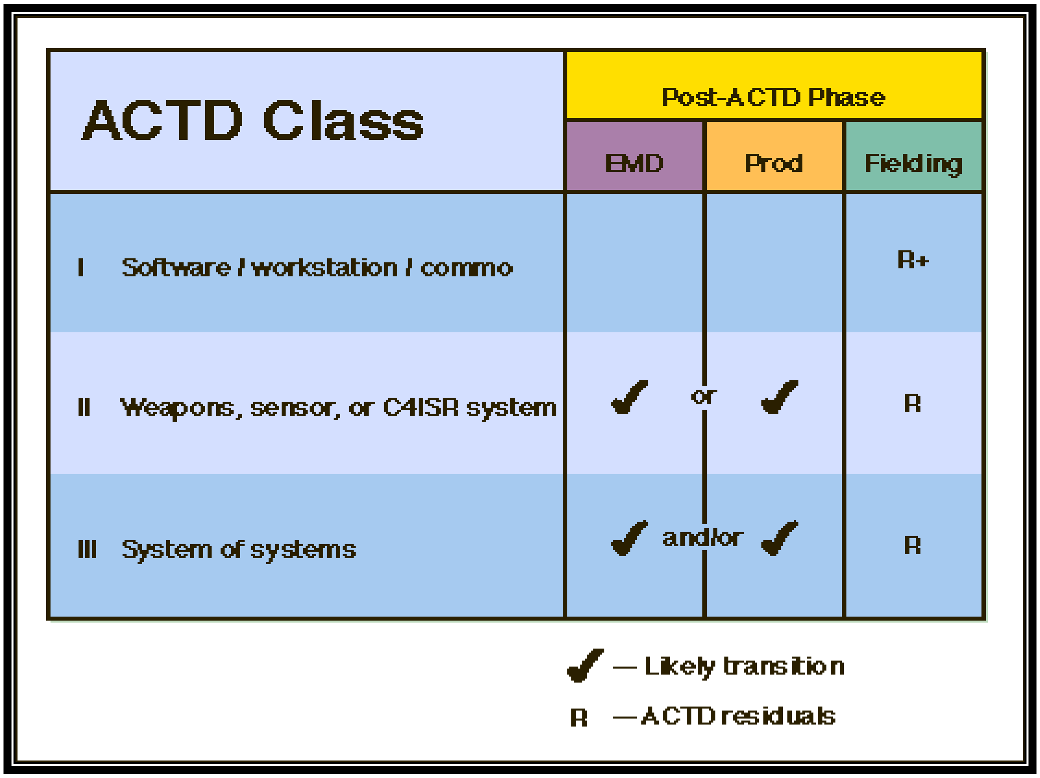

Figure 4. Classes of ACTDs (From Ref. ACTD 2004).

B. ADVANCED TECHNOLOGY ORDNANCE SURVEILLANCE (ATOS)

1. Introduction

From major distributions sites, such as, Naval Surface Warfare Centereapons, Indian Head Division, Maryland, and Crane Army Ammunition Activity, Crane, Indiana, to the warfighter, the effective management practice of overseeing munitions has long been hindered by labor-intensive inventory methods and stockpile inaccuracies. The status quo (or "as-is") transaction process involves tedious manual data entry using inventory sheets to track and monitor the flow of munitions. The loss of asset visibility due to database munitions inaccuracies adds to the creation of a host of problems for the acquisition manager, logistician, storage custodian, and most importantly, the warfighter in the field. These problems cause the overall mission readiness to be degraded, because needed munitions either cannot be located, or when located, their reliability is unknown because the current surveillance methods fail to provide the critical environmental information required to determine munitions' serviceability and reliability. Knowing munitions storage conditions, specifically temperature, relative humidity, and gravity shock, can have significant impact on munitions' safety and reliability. By taking advantage of the latest in Automatic Identification Technologies (AIT) and Micro-Electromechanical Systems (MEMS), all stakeholders should have a capability that provides near real-time environmental information and automated support for managing their respective munitions stockpiles.

Micro-Electrical-Mechanical Systems (MEMS) are promising new technologies that facilitate a new dimension of Focused Logistics support. As the website http://www.memsnet.org/mems/what-is.html describes it,

> MEMS is the integration of mechanical elements, sensors, actuators, and electronics on a common silicon substrate through microfabrication technology. While the electronics are fabricated using integrated circuit (IC) process sequences (e.g., CMOS, Bipolar, or BICMOS processes), the micromechanical components are fabricated using compatible "micromachining" processes that selectively etch away parts of the silicon wafer or add new structural layers to form the mechanical and electromechanical devices. MEMS promises to revolutionize nearly every product category by bringing together silicon-based microelectronics with micromachining technology, making possible the realization of complete systems-on-a-chip. MEMS is an enabling technology allowing the development of smart products, augmenting the computational ability of microelectronics with the perception and control capabilities of microsensors and microactuators and expanding the space of possible designs and applications.
>
> Microelectronic integrated circuits can be thought of as the "brains" of a system and MEMS augments this decision-making capability with "eyes" and "arms", to allow microsystems to sense and control the environment. Sensors gather information from the environment through measuring mechanical, thermal, biological, chemical, optical, and magnetic phenomena. The electronics then process the information derived from the sensors and through some decision making capability direct the actuators to respond by moving, positioning, regulating, pumping, and filtering, thereby controlling the environment for some desired outcome or purpose. Because MEMS devices are manufactured using batch fabrication techniques similar to those used for integrated circuits, unprecedented levels of functionality, reliability, and sophistication can be placed on a small silicon chip at a relatively low cost.

Through the use of real-time sensor data, MEMS provides improved situational awareness and asset visibility within a small and inexpensive form. MEMS technology uses modern electronics fabrication techniques with micro machining to provide advanced functionality on a silicon chip. Through proof-of-concept projects, U.S. Army Logistics Transformation Agency (LTA), a field operating agency of the Deputy Chief of Staff, G-4, is bringing active Radio Frequency Identification (RFID) devices together with MEMS to capture, record, and communicate temperature, humidity, shock, light and other environmental conditions. When combined with track and trace capability of active RFID, these prototype devices can provide stand-off asset visibility, self-reporting communications, and data storage functions to record, alert and provide immediate feedback to soldiers and logisticians on the condition of assets. Potential applications for MEMS span all classes of supplies and logistics processes including perishable subsistence, diagnostics/prognostics in maintenance, individual protective equipment, medical supplies, ammunition, fuel, inventory and shelf life management, and weapon system condition "health" monitoring.

The LTA is examining the application of commercially available MEMS-based sensors with active RFID to track and report environmental factors that affect the viability of Class VIII medical supplies. At present, hundreds of thousands of dollars are expended annually on the cost of labor to accomplish manual processes related to monthly visual monitoring of humidity control devices on Class VIII DEPMEDS in long term storage at Sierra Army Depot (SIAD). Additionally, millions of dollars of Medical Sets, Kits and Outfits (MESKOs) materiel had to be destroyed by U.S. Army Medical Materiel Center-Europe (USAMMC-E) in 2003 due to the effects of unknown environmental conditions that the materiel had been exposed to while in transit or storage. LTA has developed a high level RFID/MEMS conceptual design analysis; a Business Process Analysis (BPA) for MEMS application to Class VIII addressing high-level analyses of Deployable Medical Systems (DEPMEDs), Medical Sets, Kits and Outfits, and Military Vaccines; and has tested RFID MEMS technologies in a laboratory setting.

2. System Description and Capabilities

ATOS is an RFID-based automated system that provides a capability to collect environmental data in near real-time and supports munitions management tasks on stored munitions pallets [AFOTEC 2004].

The implementation of ATOS data rich RFID tags is not meant to replace any of the traditional business processes of Ordnance Management (OM). Rather, ATOS tags are meant to enhance many current processes and add additional capabilities to OM.

The following are six ATOS oriented munitions management tasks which form the foundation for inventory management of munitions:

- Munitions Receipt
- Inventory Maintenance
- Munitions Movement
- Munitions Issue
- Munitions Transfer
- Munitions Quality Assurance (QA)

Figure 5 depicts graphically how ATOS automates these tasks

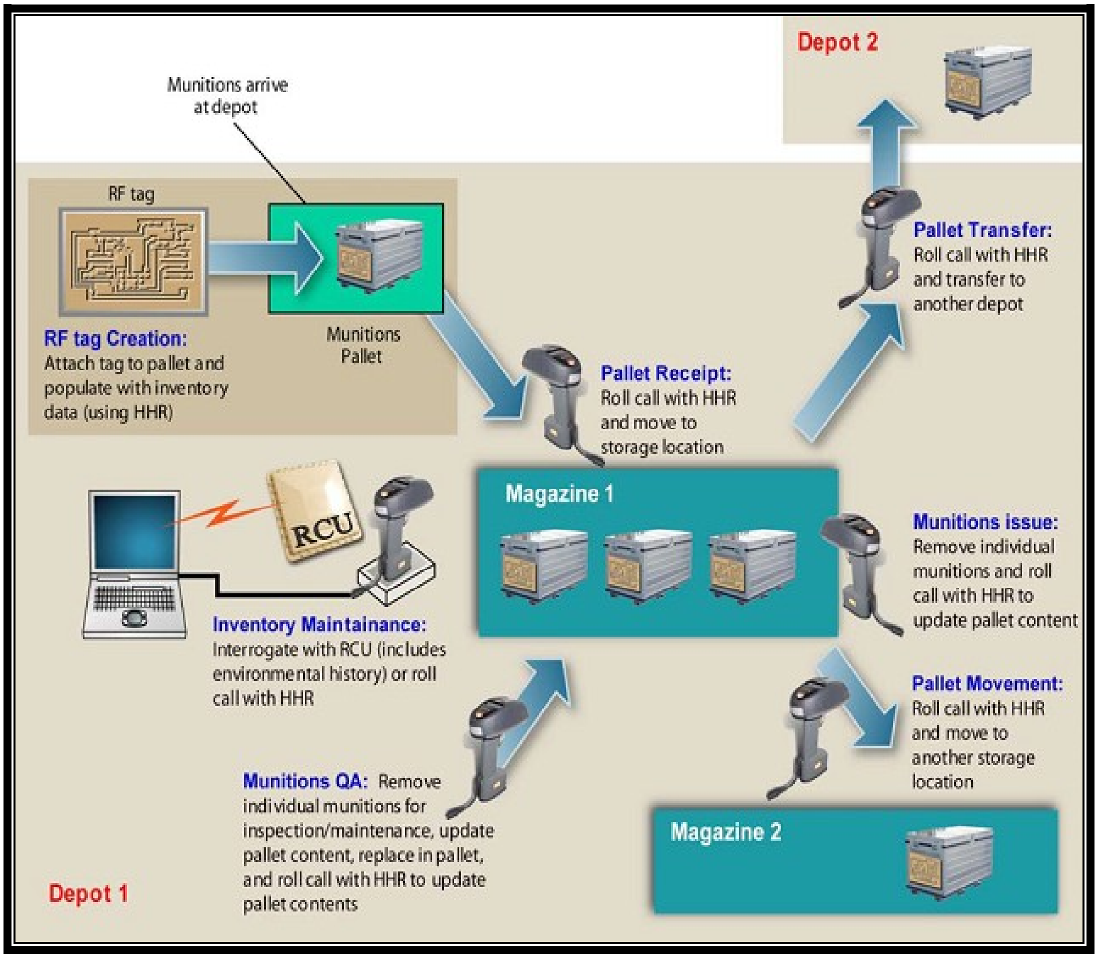

Figure 5. ATOS Automated Munitions Management Functions (From Ref. AFOTEC 2004).

The ATOS system consists of six major components:

1. RF tag,
2. Handheld Reader (HHR),
3. Reader Control Unit (RCU),
4. Pre-Processor (PP),
5. Environmental Database (EDB), and
6. An interface to service ammunition Automated Information System (AIS).

Radio Frequency Extenders (RFE) are used to enhance RF coverage inside larger enclosed magazines or depots.

The RF tag is a small enclosure attached to a munitions pallet using an RF tag holder. The RF tag contains temperature, relative humidity (RH), and gravity-shock sensors. The temperature and RH sensors collect environmental data according to a specified period of time. The RF tag also has a receiver, transmitter, and non-volatile memory to receive, transmit, and store unique asset information and environmental data. The HHR is a portable wireless barcode scanning device with the capability to read and write asset data to and from the RF tags and reads linear and two-dimensional barcodes. Using a keypad and touch screen, the user can upload and download asset information to and from the RF tags using a function called roll call, which queries the RF tag to identify itself and provide any changes to asset and environmental data. Data are stored in the HHR as transaction records until they are transferred to the PP for analysis and archived. The HHR can also retrieve stored RF tag data from the RCU using an Ethernet cable. The HHR uses a Windows Pocket Personal Computer operating system, which is a commercial off-the-shelf technology (COTS) software.

The RCU is a fixed RF reader that collects asset and environmental data from the RF tags. The RCU is powered by 24 volts direct current (VDC) and can be mounted inside a munitions magazine. Depending on the size of the magazine, RFEs are connected in series with the RCU to achieve optimal RF transmission coverage. The RCU obtains data from the RF tags using a function called interrogation, which consists of two independent reads (short and long). The short read determines the number of RF tags detected, RF tag identification (ID), Department of Defense Identification Code (DODIC), National Stock Number (NSN), consignee, any environmental sensor flags, and a low battery flag. The time duration for a short read depends upon the number of RFEs connected in series with the RCU, the number of RF tags detected inside the storage facility, and the type of material (wooden crates and aluminum pallets) on which the RF tags were attached. The long read downloads the remaining asset information and environmental data. The duration of a long-read can take hours to days depending on the number of RF tags being interrogated. The RCU serves as a long-term data storage unit for receiving and storing interrogated RF tag data. The RCU stores these data until the PP commands it to transfer the data via a wireless local area network (WLAN), local area network (LAN), serial cable connection with the HHR. The RCU has no direct user interface, i.e., no keyboard or display.

The PP is an interactive command and control system designed to retrieve RF tag data from the RCU and HHR. The PP is typically located in the central work area. Munitions information is formatted and passed from the PP to the service ammunition AIS, such as the Retail Ordnance Logistics Management System for the U.S. Navy local and theater inventory management of munitions, and the EDB. Munitions experts and analysts can use the Environmental Database to evaluate munitions performance fluctuations due to environmental changes.

Figure 6 shows the connectivity for the ATOS system components.

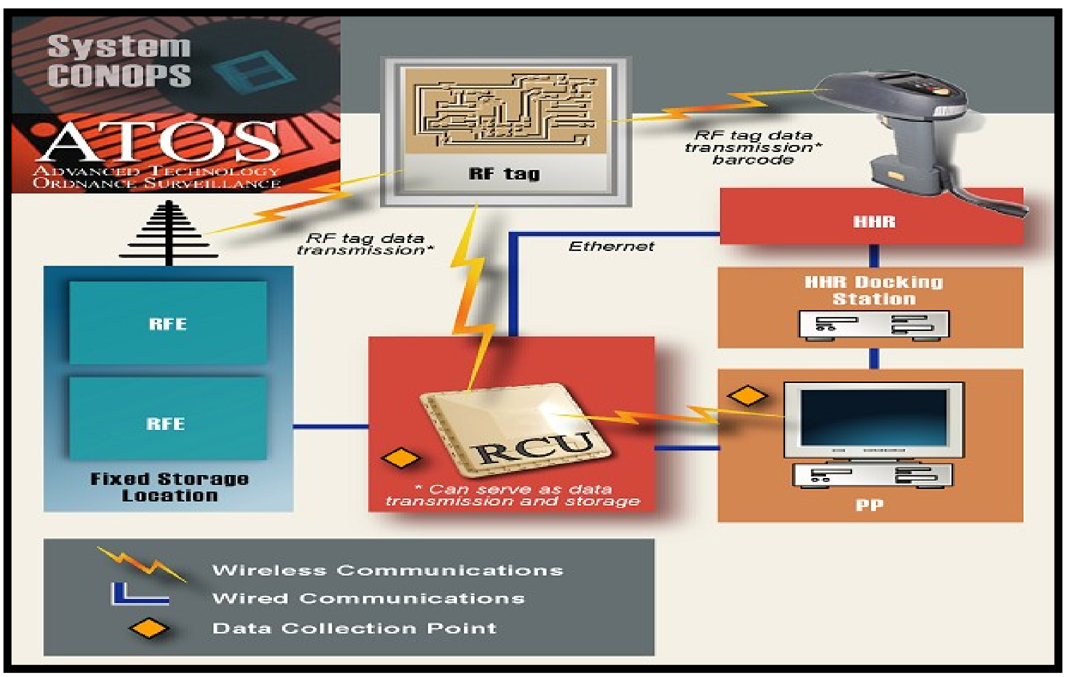

Figure 6. ATOS System Architecture (From Ref. AFOTEC 2004).

III. ATOS BUSINESS CASE ANALYSIS

A. WHAT IS A BUSINESS CASE ANALYSIS (BCA)?

A Business Case Analysis examines and compares the benefits, costs, and uncertainties of each alternative to determine the most cost effective means of meeting the objective. It is a systematic approach to the problem of resource allocation, comparing two or more alternatives in terms of cost and benefits.

The standard steps in a BCA are below:

- Objectives of the action being considered
- Specification of assumptions/constraints
- Identification of alternatives
- Listing of benefits for all feasible alternatives
- Cost estimates for each feasible alternative
- A ranking of alternatives in terms of costs and benefits
- Risk/uncertainty analysis
- Conclusions/recommendations

Decisions about mission and business planning are important because they become the basis for deciding whether an acquisition will be funded. Budget constraints are the main reasons that force organizations to justify their spending, because if there were no budget constraints, then we could buy anything and everything, and not have to engage in making choices. A BCA is a process for preparing a structured proposal that establishes sound business decisions for proceeding with an investment/project by providing decision makers with the insight into how the investment/project supports the business needs and strategic goals. The BCA structures the assessment by providing necessary information concerning the scope, alternatives considered, estimated costs and Return on Investment (ROI), and risks necessary for decision makers to make an informed funding decision for the investment/project. Therefore, budget constraints cause an increase in the usage of Business Case Analysis (BCA).

Each BCA will be different depending on its application. However, a BCA structure should include the following as a minimum [ACC 2004].

- Introduction. It presents the objectives addressed by the subject of the case, and all the options, including the status quo, considered to achieve the objective.
- Assumptions and Methods. Outlines the rules for deciding what belongs in the case, and what does not, along with the critical assumptions.
- Business Impacts. The main business case results.
- Sensitivity and Risk Analysis. Shows how results depend on the important assumptions ("what if"), as well as the likelihood for other results to surface.
- Conclusions and Recommendations. Recommends specific actions based on business objectives and the results of the analysis.

1. The BCA Process

Figure 7 displays the BCA process consisting of four steps.

- Definition is the first step in the BCA process and sets the scope of the problem. During this step, the assumptions and the constraints are formulated which will guide the analysts of the BCA Team throughout the process. Also in this step, alternatives to be considered are identified, as well as the measures.
- Data Collection is the second step in the BCA process and is where the source and types of data to be collected are identified. The collection of data may be difficult because the data may be obscured in databases in remote locations or buried in budget documents.
- Evaluation Analysis is the third step in the BCA process and is where the "number crunching" is done. In this step, the data that was

collected in the second step is used to build a case for each alternative, using both qualitative and quantitative data. Each alternative is compared against each other, in an effort to identify a best alternative. It is important that analysts should not only seek to determine which alternative has the lowest cost, but which alternatives provide the optimal combination of price and performance.

- Results Presentation is the fourth step in the BCA process. This is a critical step because if the BCA Team is unable to communicate effectively the results to the decision makers, the analysis is worthless. Conclusions are to be organized around the objectives stated up front in the case. The recommendation of the BCA will consist of recommending to stay with the status quo or to adopt the alternative(s) being considered.

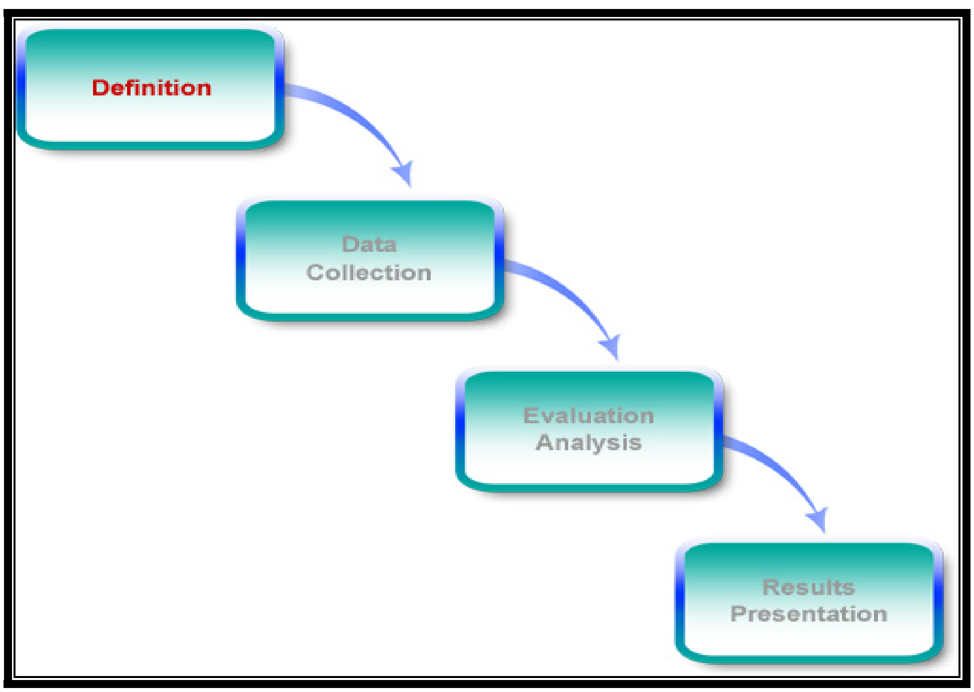

Figure 7. The Business Case Analysis Process (From Ref. ACC 2004).

B. WHAT IS A WORK BREAKDOWN STRUCTURE (WBS)?

A Work Breakdown Structure (WBS) is a hierarchical approach to plan and integrate the various parts of a project. The Department of Defense Handbook, MIL-HDBK-881, defines a WBS as follows:

- A product-oriented family tree composed of hardware, software, services, data, and facilities.
- The family tree results from systems engineering efforts during the acquisition of a defense materiel item.

The following are a few benefits of how a WBS may assist a Program Manager (PM) during the life cycle of a program [MIL-HDBK-881].

- Separates a defense materiel item into its component parts, making the relationships of the parts clear and the relationship of the tasks to be completed-to each other and to the end product-clear.
- Affects significantly planning and the assignment of management and technical responsibilities.
- Assists in tracking the status of engineering efforts, resource allocations, cost estimates, expenditures, and cost and technical performance.
- Helps ensure that contractors are not unnecessarily constrained in meeting item requirements.

By displaying and defining the efforts to be accomplished, the WBS becomes a management blueprint for the product and reduces the likelihood of something falling through the cracks.

1. Work Breakdown Structure for ATOS

To be able to provide a realistic BCA of the implementation of an ATOS infrastructure at a Navy Munitions Management location, the advice of Subject Matter Experts (SMEs) from Naval Surface Warfare Center (NSWC), Indian Head Division, was seek to validate the additional sustained cost in fielding ATOS. The top level WBS is composed of the following components:

- Investment
- Operation and Support (O&S)
- Environmental

The ATOS infrastructure at a Munitions Management facility will consume the biggest portion of the investment funding due to the amount of equipment/software, installation cost, and personnel training needed for the newly fielded system. Of course, the number of munitions magazines and the number of munitions in a facility will dictate the true implementation cost.

Operation and Support consists of the costs needed to sustain the ATOS infrastructure. The recurring costs are the cost incurred to continue the validation of models and to maintain the readiness of the system, i.e., to replace equipment/software due to damage, normal wear and tear, and system upgrades throughout the life cycle of the system.

Critical environmental information, e.g., munitions storage conditions, is needed to determine munitions' safety, reliability, and performance. The status of the munitions is critical for the following three reasons:

1. Safety. Munitions accidentally exploding in munitions magazines or afloat without warning pose great danger to personnel and property.

2. Reliability. Warfighter should have reliable munitions they depend on a daily basis. When munitions is intentionally launched or fired (pulled the trigger), the munitions should leave the canister of a Vertical Launch System (VLS) or the muzzle of a gun without delay. The life of the warfighter may be on jeopardy.

3. Performance. When the munitions have been launched, they are expected to perform to their specifications, i.e., fly at their intended speed and correct altitude, for mission success and accomplishment.

The collection of environmental data, such as time-phased histories of temperature, humidity, and shock for the munitions under surveillance, is for munitions incident prevention. Knowing the reliability and the shelf life of munitions are key in munitions incident prevention. Being conscious of the storage/environmental factors munitions are experiencing or have experienced in the field, can lead to the prevention of munitions magazines from inadvertently exploding due to munitions instability or shelf life expiration, thereby, saving in the clean-up effort, collateral damage to property, or more importantly, the safety of personnel.

We spoke to Subject Matter Experts whose recollection is that incidents have occurred only ashore, and not afloat. This is because ashore munitions management facilities intentionally accelerate ("cook-off") the shelf life of munitions. This serves as a munitions plan to advise afloat units about the serviceability and reliability of their munitions onboard.

Subject Matter Experts also say that two incidents, one in 1970 and one in 1994, are the only incidents that have occurred in the last three decades, and that in these two incidents, gun propellant was the common denominator. That is about one incident every twelve years or 0.1 incidents per year.

ATOS will play a key role in Quality Evaluation (QE), also known as Surveillance. The mission of QE is to determine the safety, reliability, and performance of munitions. When QE is accomplished, munitions are dissected to determine the status of similar munitions. Obviously, dissected munitions are lost munitions to the inventory. According to Subject Matter Expert, Mr. Roger Swanson, NOSSA (N8), Director Weapons Assessment, it is impossible to conduct QE on all DoD's munitions stockpiles because of funding constraints and time. For this reason, the current program only has QE personnel conduct QE on selected munitions that have the greatest susceptibility to the environment. For example, QE on a missile's rocket motor is accomplished once every three years depending on the rocket's propellant composition. Under the current practice, munitions are added to the QE list only when a mishap occurs. This procedure has the disadvantage that we react after the fact, i.e., after a mishap has occurred. ATOS, with its potential to collect the necessary environmental munitions data fixes this disadvantage because QE will be done on all munitions vice just the selected few.

The RFID tags attached to munitions pallets will have the capability to collect data on temperature, humidity, and shock of all munitions. These data, provided to QE personnel, can be analyzed with the right models to predict with a high degree of accuracy the safety, reliability, and the performance of the munitions the warfighters are employing in theater on a daily basis. The funding for model development and implementation will be a recurring cost for fielding ATOS.

C. "AS-IS" COST (A WORLD WITHOUT ATOS)

1. Ordnance Management Process

The current Ordnance Management process is labor intensive. It entails the manual data entry using inventory sheets to track and monitor the Department of Defense munitions stockpiles. In this process, personnel physically have to conduct every munitions management task, i.e., physically count all munitions in a munitions magazine when conducting an inventory. Many man-hours are spent doing any one task which can be translated to hundred of thousands of dollars per year. Additionally, the manual effort is subject to errors, which then yield an inaccurate database.

The following six munitions management tasks that form the foundation for the inventory management of munitions used in the Military Utility Assessment by AFOTEC demonstrates how labor intensive the current process can be [AFOTEC 2004].

1. Munitions Receipt. When munitions arrive at a Munitions Management facility, personnel need to be available for receiving the munitions, move the munitions to the storage location, and add the munitions to the current inventory.

2. Inventory Maintenance. Personnel physically need to count all munitions in a munitions magazine to maintain inventory information on all magazines. The inaccuracy of this inventory information is subject to human error.

3. Munitions Movement. When munitions are moved from one magazine to another, personnel need to do the manual data entry that reflects the change

to the magazine inventory. Again, the inaccuracy of this inventory information is subject to human error.

4. Munitions Issue. When munitions are issued to the warfighter, personnel need to update the magazine inventory and the munitions database to reflect the current inventory. Again, the inaccuracy of this inventory information is subject to human error.

5. Munitions Transfer. When large amounts of munitions are shipped to another Munitions Management facility or to the warfighter in theater, personnel need to manually conduct the data entry to reflect the munitions transfer at both the munitions database and the magazine inventories. Again, the inaccuracy of this inventory information is subject to human error.

6. Munitions Quality Evaluation/Surveillance. When QE personnel remove munitions for inspection, the results of the inspection or condition of the munitions need to be recorded in the munitions logbooks. Again, the inaccuracy of this inventory information is subject to human error.

2. Ordnance Management Cost

The current Ordnance Management process used to manage DoD's large munitions stockpiles does not track the status of all munitions in the inventory, but yet is costing DoD millions of dollars a year. The following describe why the current management process of munitions has caught the attention of DoD.

Demilitarization of all munitions is performed and paid by the U.S. Army. The Department of the Navy alone in FY00 generated over 16,000 tons of ordnance that needed demilitarization and disposal at an average cost of $892 per ton of material for a total cost of over $14M. The Army's disposal budget would be greatly reduced if the services found a way to expend a greater portion of its munitions before they become obsolete and require high cost to dispose [Herb].

Corrosion is another challenge for DoD. It affects mission readiness and adds additional cost in shipping replacement munitions. Corrosion is defined as a chemical reaction between a material, usually a metal, and its environment that produces a deterioration of the material and its properties. Changes in the environment, i.e., changes in temperature and humidity, cause munitions to corrode thereby costing DoD millions of dollars in corrosion maintenance. While corrosion is a problem for all services, not just the USAF, we can gain an appreciation of the magnitude of the problem reported in the final report submitted February 16, 2005, by C^2 Technology, Inc, to the USAF on the cost of corrosion. This report states that the USAF in FY04 spent $43M in munitions corrosion maintenance.

Munitions handling can be a dangerous evolution because munitions can be accidentally dropped and depending on the condition of the munitions, they can either explode or they do not explode. If munitions are dropped and they do not explode, the current procedure has these munitions shipped to a location where they can be investigated for damages. This would be great for single munitions, e.g., a missile. If a pallet of munitions is dropped instead, the entire pallet is being shipped to be checked for damages because personnel cannot determine the condition of the munitions in the pallet. Not all munitions may be damaged, but there is currently no way of determining the condition of all munitions in the pallet. The inability to determine the condition of the munitions affects mission readiness and adds additional cost in shipping replacement munitions.

The purpose of the Quality Evaluation program is for DoD to continuously monitor and track the safety, reliability, and performance of only selected munitions to ensure these munitions stockpiles are at their highest state of readiness. As previously mentioned, it is impossible to do QE on all munitions stockpiles. Munitions are added to the QE list only after a fleet or ashore incident has occurred. According to Mr. Roger Swanson, in FY08 and onwards he will receive a budget of $3M to support QE on only surface ordnance. This $3M is used for destructive testing/inspection and to conduct analysis to determine the service life and to revise the maintenance schedule, if necessary, for the munitions. Additionally, he requires an additional $1.5M a year for test equipment used in testing munitions stockpiles for bit checks. Bit checks only indicate whether the munitions are good or bad, i.e., up or down. If it indicates down, additional testing and maintenance is required to determine the failure. Testing equipment does not indicate how the munitions will perform once launched. The destructive testing/inspection and analysis done produce the ultimate results desired to find out how munitions will perform when launched.

Destructive testing/inspections on munitions, e.g., a missile's rocket motor, are done every three years depending on the rocket's propellant composition. According to Mr. Swanson, a complete QE costs $0.5M per rocket. This does not include the buying of the replacement rocket required to return the missile to a state of mission readiness. Again, depending on the rocket's propellant composition, a rocket will cost the service between $50,000 and $250,000.

Although munitions mishaps hardly ever occur afloat or ashore (0.1 incidents per year), the cost they can incur cannot be overlooked. In the 1994 munitions incident, the cost to DoD was over $1M for the destruction of the munitions magazine, $590,000 for the lost of munitions, and $400,000 for the clean-up efforts. This does not include the investigation cost to DoD to determine the cause of the explosion.

D. "TO-BE" COST (A WORLD WITH ATOS)

1. Ordnance Management Process

The implementation of ATOS, as previously mentioned, is not meant to replace any of the current traditional business processes of Ordnance Management. Rather, ATOS is meant to enhance the current Inventory Management process and add additional capabilities to Ordnance Management, e.g., the system will be capable of automatically monitoring and reporting user defined environmental conditions experienced by the munitions in near real-time. Additionally, by implementing ATOS the number of labor intensive man-hours expended in accomplishing the current Inventory Management process discussed above, can be greatly reduced.

The following is a description of how the six munitions management tasks of the Inventory Management process used in the MUA by AFOTEC can be improved when using ATOS so that the reduced workload can allow for other productive efforts to be accomplished [AFOTEC 2004].

1. Munitions Receipt. When munitions arrive at a depot, munitions or logistics personnel attach RF tags to munitions pallets and populate RF tags with asset information for each munitions pallet using the HHR. Next, tagged munitions pallets are receipted and the asset information is stored on the HHR as a transaction record. Tagged munitions pallets are moved to a storage location where the RCU retrieves the asset information and the latest environmental data from the munitions pallets. The RCU updates and stores the RF tag data until the PP commands it to transfer the data via WLAN, LAN, or the HHR serial port. The PP reconciles the transaction records from the HHR and RCU data, updates the inventory list, and graphically displays the data on the computer screen.

2. Inventory Maintenance. The RCU maintains the munitions inventory through periodic interrogations of the RF tags. If the RCU encounters a new or missing RF tag, it sends a flag to the PP. When conducting inventory tasks using an HHR, the ATOS operator first downloads the inventory list from the PP to the HHR. The operator then takes the HHR to the magazine. The HHR queries the RF tags and reconciles the inventory list with the tagged munitions pallets inside the magazine. Any new or missing RF tags are flagged by the HHR and associated data are later transferred to the PP. The operator takes appropriate actions to resolve any flags that were sent to the PP from the HHR or RCU. Throughout this process, the RF tags continually collect and store environmental data.

3. Munitions Movement. When tagged munitions pallets are moved from one location to another within the same depot, the operator uses the HHR to update the RF tag location information. On the next interrogation, the RCU automatically updates location data on the PP inventory list.

4. Munitions Issue. The operator issues one or more individual munitions items from tagged munitions pallets to a local field unit and uses the HHR to update the munitions count on the RF tag. The RCU captures the munitions count change and updates the PP inventory list.

5. Munitions Transfer. The operator ships a tagged munitions pallet to a location outside of the depot, using the HHR to document the transfer. The operator

uses the HHR to download the latest asset information, environmental data, and any alarm flags. The HHR is docked to the PP and data are transferred to the PP. The RF tag ID number is removed from the inventory list and the data are archived. The PP automatically updates the inventory records of the losing depot when the HHR is docked to the PP. Munitions pallets are not tracked while in transit between depots, but the RF tags will continue to collect environmental data, which is transferred to the PP at the final destination.

6. Munitions Quality Evaluation/Surveillance. The operator removes one or more individual munitions items from tagged munitions pallets for inspection/maintenance. QE personnel use the HHR to update the pallet condition code and history to reflect the status of the individual munitions items and what QE actions were taken upon its return to the inventory. The RCU captures the updated information and transfers it to the PP. The PP then reconciles the RCU and HHR data and updates the inventory list.

2. Ordnance Management Process Cost

There are many benefits in implementing an ATOS infrastructure. One of the main objectives is to reduce the cost of the current Inventory Management process. The initial fielding of ATOS will be the additional cost incurred in the first year. From the second year onwards, DoD will benefit from the dividends that ATOS provides in the inventory of munitions. For the dividends in the environmental, munitions environmental data needs to be collected for at least a ten-year time frame. The following describe how ATOS changes the current management of munitions.

Manpower costs are expected to be reduced because personnel no longer have to do the wall to wall inventories that can take many man-hours. ATOS provides magazine inventories near real-time. Additionally, many man-hours are saved in the receipt of munitions because documents, such as DD1348-1 forms, will be obtained from the accountable officer and uploaded directly into the handheld readers.

Demilitarization is another area in which DoD can save millions of dollars a year. There is currently no implemented method that identifies the condition of all munitions in inventory. Quality Evaluation done in selected munitions is the only method that exists that identifies the serviceability and reliability of munitions. If munitions of a specific batch are identified as "bad" munitions, the entire batch manufactured on the same date are removed from inventory and taken to be demilitarized. This is also true for munitions that are accidentally dropped. If the dropped munitions tested "bad", the entire pallet of dropped munitions is removed from inventory without further testing.

The ability to gather environmental data munitions are experiencing or have experienced in the magazines, in transit, or in the field, can reduce the millions of dollars DoD is currently spending in corrosion maintenance. The environmental data collected can be used to change the environmental conditions under which the munitions are being stored. Additionally, this can assist personnel in revising the maintenance schedule of munitions stored under different conditions, i.e., in the field vice being stored in a munitions magazine.

The collection of munitions temperature, humidity, and shock/vibrations will be used as input data for models to determine the munitions service life and to revise maintenance schedule of all munitions, instead of just the current munitions on the QE list. This ATOS initiative will significantly enhance the QE process.

According to Mr. Swanson, ATOS has the potential to reduce QE expenditure by as much as 83% as there will be no need to conduct destructive testing/inspection of munitions as the QE program currently calls for. This does not mean that destructive testing/inspection will be terminated. This type of testing will still be required but over a longer period of time, i.e., ten years vice three years, to validate and improve the working models.

The cost of developing and validating models depends on the models' complexity, and the cost is comprised almost exclusively of labor costs which come with a decent price tag. I anticipate that the type of model that will be required to assist in QE of munitions will cost about $1.5M annually.

E. METHODOLOGY FOR ASSESSING CHANGES DUE TO ATOS IMPLEMENTATION

For each Element in the ATOS Work Breakdown Structure, a judgement is made on what percentage reduction in the As-Is costs is caused by the implementation of ATOS. These percentage reductions will be SME-based for this thesis and pilot-project-data-based in the future.

The reason these percentage reductions are SME-based is because there has not been an ATOS pilot program implemented long enough to collect sufficient data to accurately annotate the realistic reductions. The ATOS pilot programs implemented thus far have been programs implemented at a lower scale to collect data to conduct, e.g., a Military Utility Assessment (MUA). These programs have been tailored to accomplish specific objectives or answer questions posed by DoD decision makers.

The Subject Matter Experts consulted in the process of thesis, have been personnel who have been actively involved in one way or another with ATOS and are currently Program Mangers at NSWC, Indian Head, or Ordnance Managers/Supervisors at Seal Beach Weapons Station. Ordnance Managers being both extremely familiar with the ordnance inventory management processes at their munitions sites and being actively engaged in the ATOS initiative are the most qualified personnel to perceive what steps in the ordnance process can be automated with ATOS implementation and what percentage reduction is realistic in the process. Of course, these are estimates and vary from munitions site to munitions site depending on the amount of munitions stockpiles being accountable for.

In the inventory management process, these percentage reduction estimates are most confident because most work done thus far in ATOS has been in this area of interest. The percentage reduction estimates in the environmental area of interest, are not with a high degree of confidence. This is because pilot programs have not been implemented to collect munitions environmental data to support these estimates. All SMEs concur that it can take 10 to 12 years of munitions environmental data collection before a rational data-supported estimate can be achieved.

The percentage reduction estimates provided by the SMEs as stated above, are our initial estimates that need to be validated by the results from pilot projects. This will occur as SMEs over time have collected sufficient data to analyze and recommend more precise estimates. At that point, the savings ATOS provides will be embraced by the services that are not now providing their full support.

Table 2 below displays the percentage reduction estimates that are used in this analysis.

F. COMPARISON OF "AS-IS" TO "TO-BE"

Two Return on Investment analysis are presented.

- The first ROI is on the impact of an investment in an ATOS infrastructure on the Inventory Management process and the successful management of DoD's munitions stockpiles. We have access to some data for this analysis, and the benefits from this investment are available to the analysts relatively quickly.
- The second ROI focuses on the impact of an investment in ATOS in the arena of munitions environmental data. This is more theoretical because data needs to be collected and analyzed over a relatively long period of time in order to address effectively the savings that ATOS can provide.

1. Inventory Management Process Return on Investment Analysis

To do the first ROI analysis of measuring the impact of an investment in ATOS infrastructure on the Inventory Management process and the successful management of DoD's munitions stockpiles implementing ATOS , I had to gather cost estimates for the Operation & Support to capture the As-Is cost. For clarification, the As-Is costs are the costs that are occurring in the current situation, which is a world without the implementation of ATOS. To determine the To-Be cost (that is, the costs that would occur in a future situation, a world with implementation of ATOS I required

- Cost estimates for the initial investment to put ATOS in place, and
- Percentage reductions in Operation & Support costs that are due to the implementation of ATOS.

Since ATOS has not yet been implemented, I was able to gather just cost information that has been expended thus far or planned to be expended to implement a portion of ATOS. An example of this kind of expenditure is for, the inventory management process. To develop, or forecast, the To-Be cost proved to be a challenge, especially when it came to the environmental because it requires the collection of munitions environmental data over time to determine effectively the percentage reduction. Only the implementation of an ATOS pilot aimed to capture munitions environmental data over a long period of time will identify a sensible percentage reduction. After many discussions with SMEs currently working in the ATOS project, I was able to get cost estimates that I could use to proceed with the ROI analysis. Cost estimates for other portions of the analysis were developed on a best guess basis. Table 2 below displays the cost estimates used in the first ROI analysis for a notional five munitions magazine. It should be noted that the implementation of these five magazines is assumed to be what would be needed for four Hellfire Missile magazines and one Standard Missile magazine.

ATOS Work Breakdown Structure	As-Is Cost (Without ATOS)	% Reduction (With ATOS)	To-Be Cost (With ATOS)	Difference in Cost
Investment ($K)				
* Hardware/Installation	N/A	N/A	77	N/A
* Modelling Validation (1)	N/A	N/A	1,250	N/A
Total Investment Cost ($K)	N/A	N/A	1,327	N/A
Operation & Support ($K) (Annual)				
* Munitions Inventory Management	1,200	50%	600	600
* Maintenance/Quality Evaluation	37.5	50%	18.8	18.8
* Munitions Demilitarization	37.8	90%	3.8	34.0
* Hardware Replacement	N/A	N/A	1.9	N/A
Total O&S Cost ($K) (Annual)	1275.30		624.46	650.85
Environmental ($K)				
* Mishap Cost	204.6	50%	102.3	102.3
* Quality Evaluation Cost	37.5	83%	6.4	31.1
* Corrosion Maintenance Cost	537.5	50%	268.8	268.8
Total Environmental Cost ($K) (Annual)	779.6		377.4	402.2
Grand Total Cost ($K)	**2054.9**		**1001.9**	**1053.0**

(1) Modelling Validation cost of $1,250K is spread over a two-year period: $625K/Year.

Table 2. Estimates Used in the ROI Analysis for a Notional Five Munitions Magazine (All Estimates are in $K).

There is no formal Navy guidance that lays out the initial investment of the implementation of an ATOS infrastructure at a munitions facility because a fully implemented ATOS infrastructure has yet to be implemented. What does exist are costs of partially implemented ATOS scenarios that were done to answer questions posed by DoD elements, such as the Air Force Operational Test and Evaluation Center (AFOTEC) which conducted a Military Utility Assessment of ATOS to determine its utility to the warfighter. The report from this assessment may be found in Appendix B of this thesis.

In a 30 July 2004 Memorandum, the Office of Secretary of Defense (OSD) Under Secretary of Logistics directed the implementation of RFID across the Department of Defense with full implementation to be competed in FY07. In an effort to meet the dateline, OPNAV N4 has taken the lead in the research and identification of a robust RFID capability, which will provide the highest Return on Investment and that requires minimal installation and out year maintenance costs. OPNAV has identified two Naval Weapons Stations, Seal Beach, California, and Yorktown, Pennsylvania, to implement an ATOS pilot. Phase I of this pilot will demonstrate how inventory can be accomplished in real time with a very high degree of accuracy and track location of sub-assembly components of high value missiles. The extent of this implementation will be to outfit four Hellfire Missile magazines and one Standard Missile magazine with the capability to provide real time inventory and asset data visibility to Ammunition Distribution & Control (AD&C). Additionally, this part of the test will demonstrate the potential ability to change current supply chain management within and between activities.

To capture the As-Is cost, I used a combination of the following:

- FY00 Army Demilitarization Cost
- Prior NPS work
- 1994 Incident Cost Report
- Estimate to outfit five munitions magazines
- FY04 USAF Corrosion Maintenance Cost Report
- SMEs best guess cost estimates

SMEs want to make it clear that the figures provided are estimates and these estimates are different from munitions facility to munitions facility.

To capture the To-Be cost of the Inventory Management process was a much harder problem. This is because, as previously mentioned, there is not enough data to determine the percentage reduction that ATOS would provide. The percentage reductions that I used are best guess estimates and need to be validated once data is collected and analyzed from a pilot project.

a. *Baseline Operation & Support ROI Analysis*

This ROI analysis model is used as the baseline for the Operation & Support of a notional five munitions magazine at a Naval Weapons Station. In this baseline model, data is taken from Table 2 above, which includes

- $1.327M to implement an ATOS infrastructure in this notional five munitions magazine, time phased as follows:
  - Year 1 - $0.712M
  - Year 2 - $0.625M
- $1.275 annual costs for the Operation & Support

To account for inflation, I used the inflation indices provided by the Naval Cost Analysis Division (NCAD). These indices are available at http://www.ncca.navy.mil/service/inflation.cfm.

For net present value computations, I assumed a 10% discount on the savings produced every year starting. These savings begin in YR 1, under the assumption that implementation of ATOS occurs in YR 0.

Figure 8 below displays the cumulative Operation & Support and Investment cost for the As-Is and the To-Be for the management of the five notional munitions magazines. Compared to the amount invested, I calculate a break even point in 24 months. That is, the notional five munitions magazines at the Naval Weapons Station will obtain full return on the initial investment in 24 months.

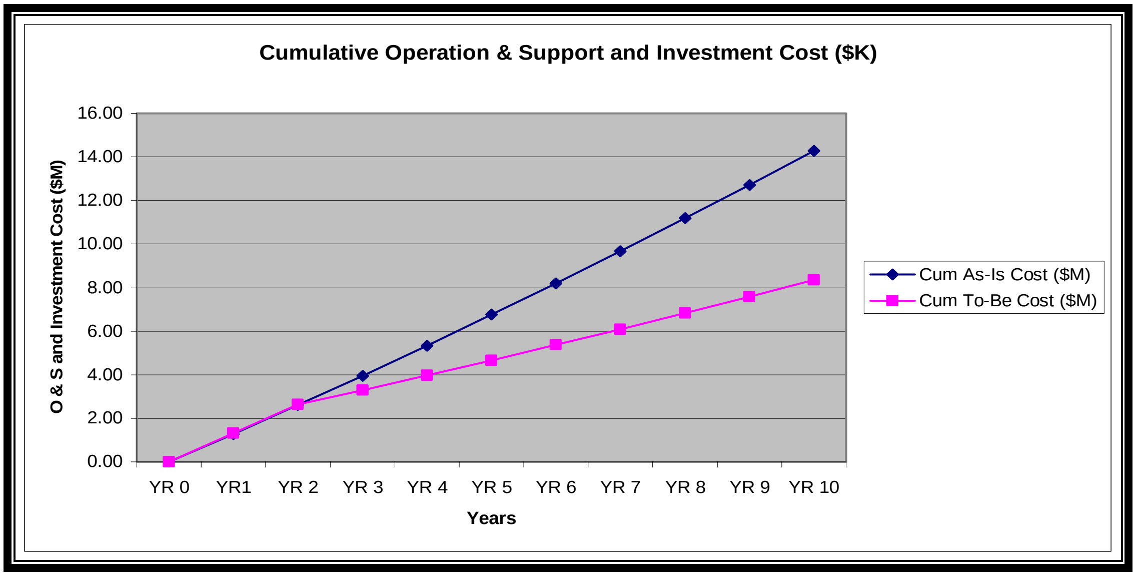

Figure 8. Cumulative Operation & Support and Investment Cost.

Figure 9 below displays the Net Present Value (NPV) of Operation & Support and Investment savings. I assumed a 10% discount on the savings produced every year starting on YR 1 since I am assuming implementation of ATOS in YR 0. With these assumptions, I calculate that the notional five munitions magazines at the Naval Weapons Station can save approximately $5.2M (undiscounted savings) and $2.8M (discounted savings) in a ten-year period by implementing ATOS in the Inventory Management process. The Return on Investment is calculated at 214 %. That is, if $1.3M was invested for 10 years at 10.8% compounded interest, one would save $2.8M which is 214% over the 10-year period, or almost 11% annual, compounded ROI.

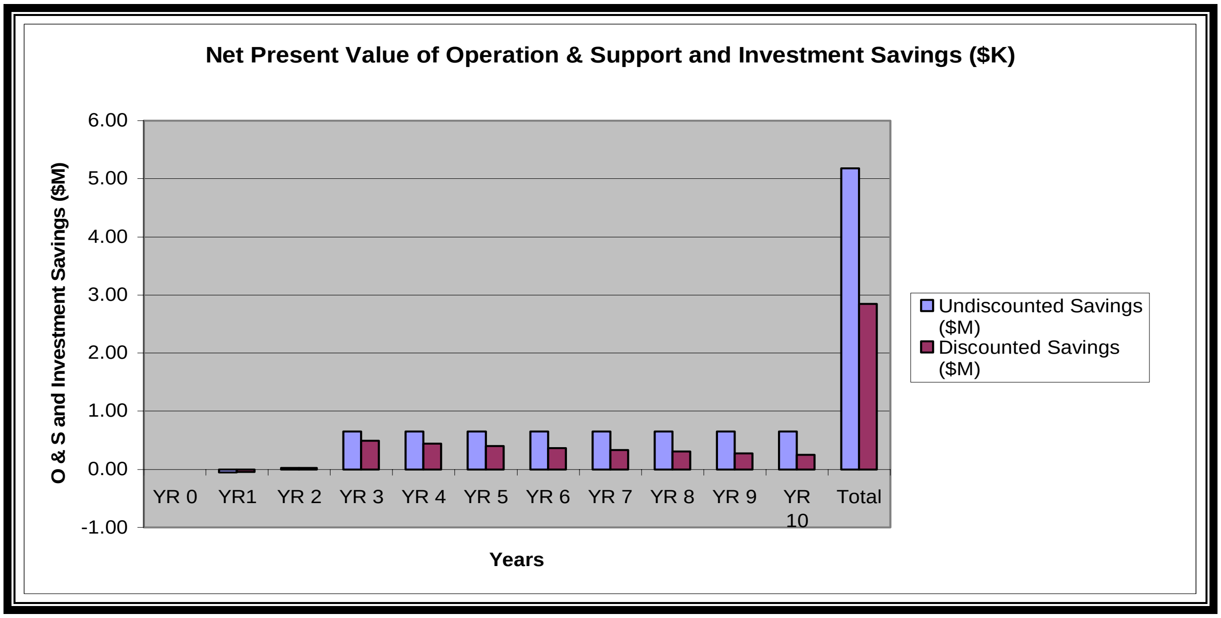

Figure 9. Net Present Value of Operation & Support and Investment Savings.

b. Baseline Environmental ROI Analysis

This ROI analysis model is used as the baseline for the Environmental cost of a notional five munitions magazines at a Naval Weapons Station. In this baseline model, I assumed it would cost $1.3M to implement an ATOS infrastructure in the notional five munitions magazines. It currently costs the notional Weapons Station $0.8M due to environmental conditions. To account for inflation, I used the inflation indices provided by the Naval Cost Analysis Division (NCAD). I assumed a 10% discount on the initial investment every year starting on YR 1 since I am assuming implementation of ATOS in YR 0.

Figure 10 below displays the cumulative environmental costs for the As-Is and the To-Be for the management of the munitions in the five notional munitions magazines. Compared to the amount invested, I calculate that the notional five munitions magazines at the Naval Weapons Station will obtain full return on the initial investment in 38 months.

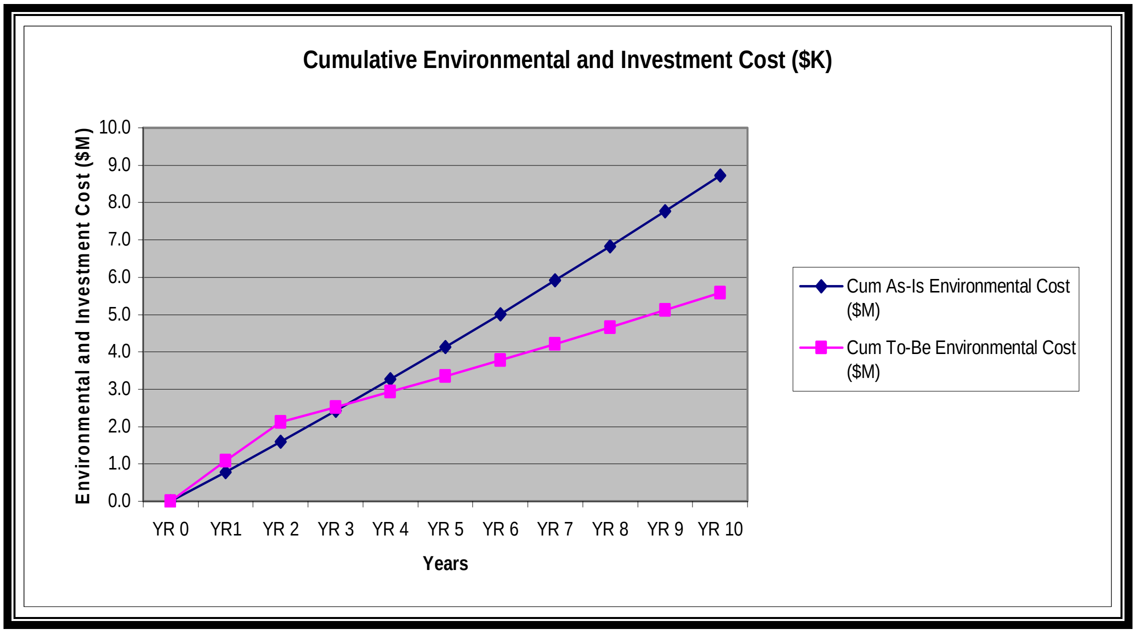

Figure 10. Cumulative Environmental and Investment Cost.

Figure 11 below displays the Net Present Value (NPV) of Environmental and Investment savings. I assumed a 10% discount on the savings produced every year starting on YR 3 since I am assuming implementation of ATOS in YR 0 and the collection of munitions environmental data for two years to collect the munitions environmental data required for analysis. With these assumptions, I calculate that the notional five munitions magazines at the Naval Weapons Station can save approximately $2.7M (undiscounted savings) and $1.3 (discounted savings) at the end of YR 10 The Return on Investment is calculated at 99 %. That is, if $1.3M was invested for 10 years at 10.8% compounded interest, one would save $2.7M which is 99% over the 10-year period, or almost 7% annual, compounded ROI.

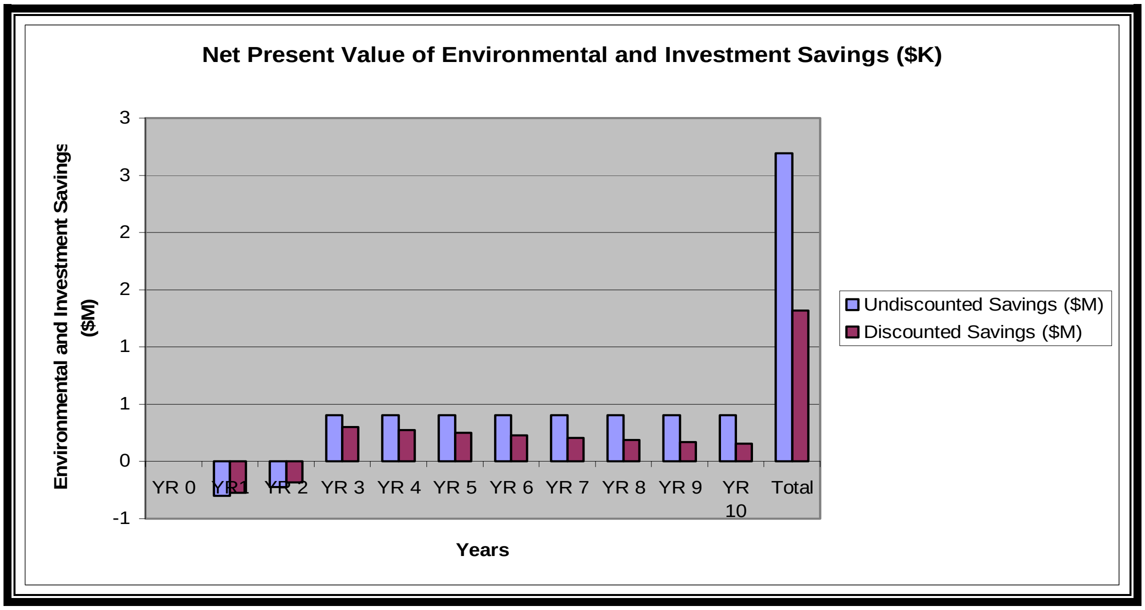

Figure 11. Net Present Value of Environmental and Investment Savings.

c. Baseline Cumulative Total ROI Analysis

This ROI analysis model is used as the baseline for the combination of Operation & Support and Environmental costs of munitions at the Naval Weapons Station. In this baseline model, I assumed it would cost $1.3M to implement an ATOS infrastructure in a notional five munitions magazine Naval Weapons Station. It currently costs the Weapons Station $2M for the Operation & Support of the five magazines. To account for inflation, I used the inflation indices provided by the Naval Cost Analysis Division (NCAD). I assumed a 10% discount on the savings produced every year starting on YR 1 since I am assuming implementation of ATOS in YR 0.

Figure 12 below displays the cumulative total cost for the As-Is and the To-Be for the management of the five munitions magazines. Compared to the amount invested, I calculate that the notional five munitions magazines at the Naval Weapons Station will obtain full return on the initial investment in less than one year.

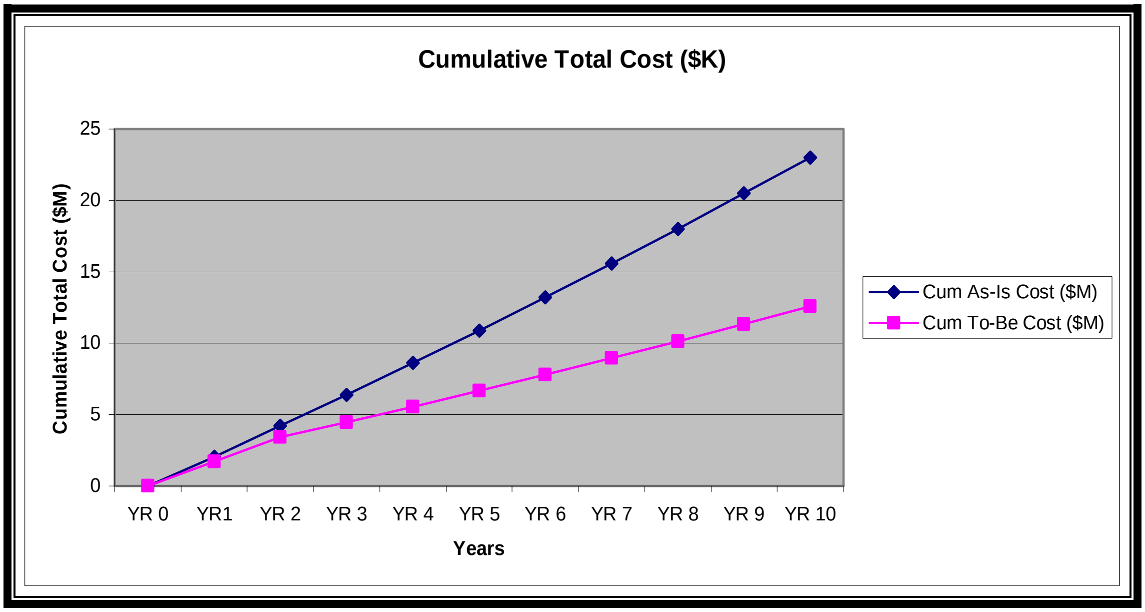

Figure 12. Cumulative Total Costs.

Figure 13 below displays the Net Present Value (NPV) of cumulative total savings. I assumed a 10% discount on the savings produced every year starting on YR 1 for the Operation & Support and YR 3 for Environmental since I am assuming implementation of ATOS in YR 0. With these assumptions, I calculate that the notional five munitions magazines at the Naval Weapons Station can save approximately $9.2M (undiscounted savings) and $5.3M (discounted savings) at the end of YR 10. The Return on Investment is calculated at 403 %. That is, if $1.3M was invested for 10 years at 10.8% compounded interest, one would save $5.3M which is 403% over the 10-year period, or almost 18% annual, compounded ROI.

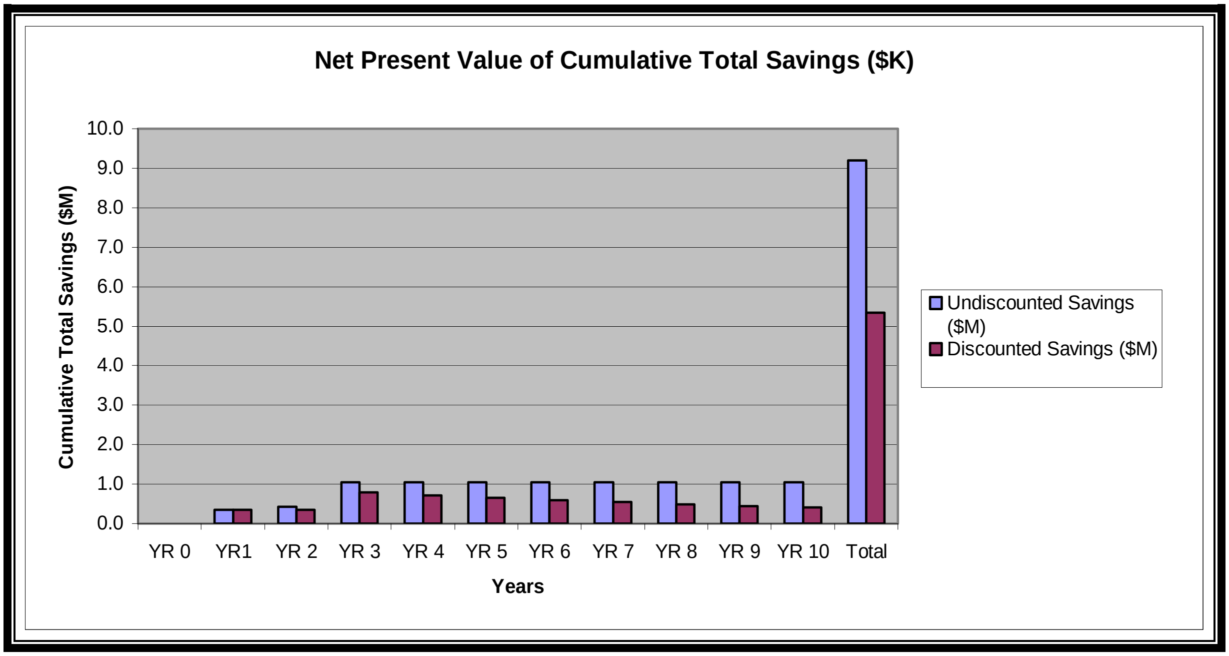

Figure 13. Net Present Value of Cumulative Total Savings.

2. Theoretical Environmental Return on Investment Analysis

As with the case with Inventory Management, we do not have historical data on what percentage reductions in Operation & Support costs ATOS implementation would provide. We do not have any data to substantiate such an estimate, so we used percentage reductions that SMEs believe that ATOS can provide over time. For those estimates that SMEs were not comfortable in providing, we provide an estimate based on our professional judgment coupled with the discussions we had with SMEs.

SMEs claim that it would take approximately ten years of environmental munitions data collection to begin analysis on the data collected. We are in the analytical position of the previous paragraph. One thing is for certain; all SMEs are in agreement that ATOS has potential savings in Quality Evaluation, Demilitarization, and Corrosion Maintenance. As previously mentioned, Mr. Roger Swanson, is confident that ATOS can reduce QE expenditures as much as 83%. Additionally, ATOS would allow all munitions to partake in the QE process vice just the current selected few. Furthermore, if during the munitions QE process, the munitions undergoing testing are found to be faulty, the entire batch of munitions manufactured on the same date is removed from the inventory and taken to be demilitarized. The current QE process assumes that if a sample of a batch manufactured on a specific date is bad, no further testing is done. The entire batch is removed from inventory to prevent personnel and property damages. With the analysis of the collection of munitions environmental data, QE personnel would be able to notify munitions sites what munitions to remove from inventory. Mr. John Backes, NSWC, Indian Head, Code E13A, says that the way of managing munitions in the future should be "management by individual instead of entire lots." The following is an excerpt from an e-mail that recaps the points discussed with an SME on his support of ATOS.

> 1) I fully support ATOS or a similar system that will provide good environmental data.
>
> 2) Management by individuals instead of entire lots should be the way of the future.
>
> 3) We can only test a small sample (usually every 3 years) of the entire population. We typically test about 30 samples and in many cases there are many more lots. We also do not have good information on the exposure of this sample and how well it represents the entire population.
>
> 4) In the future, I think we can develop a model that quantifies how much damage occurs from each environmental stressor. The model would predict when the unit was approaching a critical level of cumulative damage. The units would then be removed from the population. Early removals would be tested to verify the accuracy of the model. For items that are susceptible to thermal damage, 1 day at 150 degrees might cause the same amount of damage as 20 days at 120 degrees or 1 year at 70 degrees.
>
> 5) The biggest benefit of this capability would be an improvement in our ability to accurately monitor and predict the quality of weapons and remove defective weapons before they become a safety or reliability problem. It is much better to predict and remove these weapons instead of finding the problem when the fleet attempts to use the item.

In demilitarization, I speculate that DoD will be able to save as much as 90% because munitions will only be demilitarized when it is actually known for certain that munitions have exceeded their serviceability and pose a danger to personnel and property. According to Mr. John Backes, when munitions are dropped, there is no testing on the spot of the incident to determine the status of the dropped munitions. The dropped munitions need to be shipped to a facility where testing can be done to determine the status of these munitions. If one of the munitions is found to be damaged due to the dropped, the entire pallet that was dropped is demilitarized. When this occurs, munitions need to be shipped to replace the dropped munitions costing DoD additional monies in shipment and munitions replacement, not to mention a possible delay in mission accomplishment. Although incidents involved dropping of ordnance do not occur frequently, I speculate that on the worst case, 50% reduction in cost can be saved if personnel know what dropped munitions have received damages and need to be demilitarized without further testing. This figure can only be validated over time with the collection of munitions environmental data.

In corrosion control, I speculate the availability of environmental munitions data can reduce the corrosion maintenance expense by at least 50%. As previously mentioned, in FY04 it cost the USAF $43M in munitions corrosion maintenance. The access to information about the environmental conditions munitions are or have been exposed to can significantly assist maintenance personnel in revising munitions maintenance schedules to ensure maximum munitions serviceability and reliability.

G. SENSITIVITY ANALYSIS

Sensitivity analysis is a procedure to determine the sensitivity of the outcomes of an alternative to changes. If a small change in a parameter results in relatively large changes in the outcomes, the outcomes are said to be sensitive to that parameter. This may mean that the parameter has to be determined very accurately or that the alternative has to be redesigned for low sensitivity. Sensitivity analysis helps to determine a range of plausible inputs to be considered when there is uncertainty about the true value of an input.

In this thesis the cost estimates used in the ROI analysis were based on personal professional judgment. They can be validated only when an ATOS pilot is implemented, and the data collected from this pilot are analyzed. The initial investment, for example, will not be the same at every munitions facility because the initial investment depends on the size of the facility and the extent of the ATOS implementation. For this reason, I conducted a sensitivity analysis varying the initial investment and the percentage reductions in various Operating and Support WBS Elements, keeping all other variables the same.

Table 3 provides the results of sensitivity analyses in which the value of the initial investment is varied. Recall that the baseline value for the initial investment is $77K. In these sensitivity analyses, the initial investment is raised, in a step-wise way, to $200K, then to $400K, and finally to $600K. This latter figure represents an expansion of almost ten times the baseline investment costs. Table 3 displays the time in months when the notional Naval Weapons Station will reach the break even point, that is, the time it takes to obtain full return on the initial investment in Operation & Support given initial hardware cost of $200K, $400K, and $600K respectively. Note that while the cost of investment expands by almost ten times the baseline investment costs, the break even time expands by much less, not even doubling. This suggests that the attractiveness of an ATOS investment is very robust.

Initial Hardware Cost ($K)	Payback Period (Months)
77 (baseline)	24
200	26
400	32
600	37

Table 3. Payback Periods in Operation & Support.

To satisfy the optimistic and pessimistic use of SMEs about the Operation & Support savings that ATOS can provide, I increased and decreased the percentage reductions in the Operation & Support keeping all other variables constant, to calculate the savings and the ROIs within the same time frames.

Table 4 below displays the percentage reductions that I used in the sensitivity analyses 1 and 2.

Operation & Support (Annual)	Baseline % Reduction	Sensitivity Analysis 1 (Increase % Reduction)	Sensitivity Analysis 2 (decrease % Reduction)
▪ Munitions Inventory Management Process Cost	50	75	40
▪ Demilitarization/Disposal Cost	90	90	50
▪Maintenance/Quality Evaluation Cost	50	90	50

Table 4. Percentage Reductions in Operation & Support.

Table 5 displays the To-Be cost, savings, the payback period, and the ROI for each case presented in Table 4.

	Baseline Analysis	Sensitivity Analysis 1 (Increase % Reduction)	Sensitivity Analysis 2 (decrease % Reduction)
Investment ($M)	1.3	1.3	1.3
10-Year As-Is Cost ($M)	14.3	14.3	14.3
10-Year To-Be Cost ($M)	8.3	4.8	10
10-Year Discounted Savings ($M)	2.8	4.8	2
Pay Back Period (Months)	24	< 12	32
Total ROI (%)	214	360	152
Annual Compounded ROI (%)	11	17	7

Table 5. Sensitivity Analysis on Changes of the Percentage Reduction in Operation & Support.

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IV. OBSERVATIONS AND RECOMMENDATIONS

A. OBSERVATIONS

- Throughout this thesis, I have emphasized many times that ATOS is not a replacement for the current policy of ordnance management. Rather, the concept of ATOS is to enhance the current ordnance management processes for the effective management of DoD's large munitions stockpiles.

- Technology required to implement ATOS is COTS technology. There is no time delay in obtaining the hardware for full implementation. Of course, as requirements and security for ATOS changes,

- The methodology for doing ROI analysis associated with the implementation of ATOS is well understood, and, with appropriate data, can be developed.

- The data to support ROI analysis associated with the implementation of ATOS are not fully available, and they need to be developed. In some cases, these data need to be developed over multi-year time frames.

- Based on projects done thus far (e.g., the Military Utility Assessment by AFOTEC (Appendix B)), ATOS can provide the capability to enhance the effective management of the large Department of Defense munitions stockpiles. See the Recommendations section below for the logical follow-on to this observation.

- Mr. Roger Swanson and Mr. Mark Mentikov, Subject Matter Experts, do warn the decision makers having the final decision in making ATOS a program of record, that ATOS savings and benefits will not be reaped in all areas of interest simultaneously. Rather, the longer the system is implemented, the more attractive will the dividends be, especially in the environmental data collection. See the Recommendations section below for the logical follow-on to this observation.

- Subject Matter Experts claim that there is not enough data on hand to determine the savings with ATOS if the environmental condition munitions have experienced was known. See the Recommendations section below for the logical follow-on to this observation.

- Millions of dollars are spent every year in corrosion maintenance and Quality Evaluation to ensure munitions are mission ready. These millions of dollars can be reduced if QE personnel had better knowledge of the status of all munitions in inventory. This is not currently the case. For this reason, the RFID tags attached to munitions pallets need the capability to collect the environmental data that is required by QE personnel to input into models to provide Ordnance Managers valuable information about the status of their munitions in inventory. The more information is known about the condition of the munitions in theater, the less number of munitions, due to their reliability, will be needed to accomplish the warfighters' assigned missions.

B. RECOMMENDATIONS

- A complete implementation of ATOS to capture munitions environmental data to be analyzed in order to predict the serviceability and reliability of munitions. Currently no personnel know what percentage reduction ATOS can provide; one could only speculate. Only a pilot when implemented for a long period of time, say 10 years, can validate our speculations. It is critical that a commitment in implementing an ATOS pilot be made soon to commence collecting the benefits.

- A full scale ATOS pilot project at a munitions location, such as, Seal Beach, needs to be funded and implemented in order to

- collect the required data in order to validate the results from previous analysis, and

- support and provide a better argument as to why ATOS is the way to go in Ordnance Management.

- To establish an ATOS implementation plan DoD wide, a study on optimizing the placement of ATOS needs to be initiated. This will help decision makers in determining the optimal locations that provide the greatest savings due to the large munitions stockpiles. For example, small munitions facilities where munitions do not have a high cycle rate may not be a high priority for the implementation of ATOS.

- RFID tags attached to munitions pallets need the capability to collect the environmental data that is required by QE personnel to input into models to provide Ordnance Managers valuable information about the status of their munitions in inventory.

C. RECOMMENDATIONS FOR FUTURE RESEARCH

This thesis provides an initial glimpse of the Return on Investment analysis of the savings and benefits that ATOS has the potential of providing the Department of Defense in managing its large munitions stockpiles. While the purpose of this thesis was to provide a methodological approach for conducting a Business Case Analysis for the ATOS ACTD, there are many opportunities to capture other complexities and variability associated with ATOS, including the following.

- It would be beneficial to the Department of Defense to know an ATOS implementation location plan to guarantee savings and benefits at the earliest stages of the ATOS implementation. An optimization model would provide the order in which munitions sites are fielded to ensure the sites with the highest cycle rate of munitions are implemented first.
- Although models may already exist that provide limited predictability about the conditions of only certain munitions, robust models will be required to process the environmental munitions data collected to effectively calculate munitions service life and reliability.
- Support and participate in the implementation of the pilot project and collect the data required to conduct a Business Case Analysis to further assist the decision makers decision in making ATOS a program of record.

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LIST OF REFERENCES

Acquisition Community Connection (ACC) [2004], *Business Case Analysis.* <https://acc.dau.mil/simplify/ev.php?ID=29857_201&ID2=DO_TOPIC>, accessed 23 October 2005.

Advanced Concept Technology Demonstrations (ACTD) [2004], *ACTD Guidelines: Transition.* <http://www.acq.osd.mil/actd/transit.htm>, accessed 24 July 2005.

Alien Technology Corporation [2005], *White Paper: EPCglobal Class 1 Gen 2 RFID Specification.* <http://www.alientechnology.com/docs/AT_wp_EPCGlobal_WEB.pdf>, accessed 28 August 2005.

Axcess, Inc [2005], *Active Radio Frequency Identification (RFID) Powers Productivity and Protection in the Enterprise.* <http://www.bitpipe.com/rlist/term/RFID.html?src=googlerfidstat_content>, accessed 22 July 2005.

Boone, Christopher [2003], *White Paper: Industry Developments and Models: The RFID Ecosystem for the Retail Supply Chain.* <http://www.bitpipe.com/rlist/term/RFID.html?src=googlerfidstat_content>, accessed 22 July 2005.

Corrigan, Christopher and Jayson Kielar, *The Value of Logistics Information to the Warfighter,* MBA Thesis, Naval Postgraduate School, June 2004.

Department of Defense (DoD) Handbook Work Breakdown Structure (MIL-HDBK-881), 02 January 1998.

Herb, Mike, CAPT, N411*, Cost Reduction & Effectiveness Improvement (CREI) Initiative PR-03: Advanced Technology Ordnance Surveillance (ATOS).*

Hozven, Marcelo and George Clark, *DoD Supply Chain Implications of Radio Frequency Identification (RFID) Use Within Air Mobility Command (AMC),* MBA Thesis, Naval Postgraduate School, December 2003.

Intermec Technologies Corporation [2004], *Supply Chain RFID: How It Works and Why It Pays.* http://www.bitpipe.com/rlist/term/RFID.html?src=googlerfidstat_content, accessed 22 July 2005.

Miertschin, Keith W. and Brian D. Forrest, *Analysis of Tobyhanna Army Depot's Radio Frequency Identification (RFID) Pilot Program: RFID as an Asset Management Tool,* MBA Thesis , Naval Postgraduate School, June 2005.

Sánchez, Joaquín A., Sergio Chávez, and Richard Nixon, *Medical Equipment Management Through the Use of Radio Frequency Identification (RFID),* MBA Thesis, Naval Postgraduate School, December 2004.

SAVI Technology [2005], *Proven RFID Solutions Driving Value.* <http://www.savi.com/rfid.shtml>, accessed 22 July 2005.

Under Secretary of Defense (USD) [2004], *Radio Frequency Identification (RFID) Policy (July 30, 2004).* < http://www.acq.osd.mil/log/rfid/rfid_policy.htm>, accessed 23 July 2005.

US Air Force Operational Test and Evaluation Center (AFOTEC) [2004], *Final Paper: Advanced Technology Ordnance Surveillance, Advanced Concept Technology Demonstration, Military Utility Assessment.*

APPENDIX A. ACTDS/JCTDS FY95 – FY 05

Year	ACTD Acronym	ACTD Name
FY2005	ASAP	Actionable Situational Awareness Pull
FY2005	CUGR	Chemical Unmanned Ground Reconnaissance
FY2005	COSMOS	Coalition Secure Management and Information System
FY2005	EOS	Epidemic Outbreak Surveillance
FY2005	JCRE	Joint Coordinated Real Time Engagement
FY2005	JEERCE	Joint Enhanced Explosion Resistant Coating Exploitation
FY2005	JFP	Joint Force Projection
FY2005	MSAT	Medial Situational Awareness in Theater
FY2005	RARE	Rapid Airborne Reporting & Exploitation
FY2005	Sea Talon	Sea Talon
FY2005	Sea Eagle	Sea Eagle
FY2005	SLED	SOCOM Long Endurance Demonstrator
FY2005	VIPER Strike	Gunship Standoff Precision Munition
FY2005	TACSAT-2	TACSAT-2 Roadrunner
FY2005	WDL	Weapon Data Link
FY2004	AT3	Advanced Tactical Targeting Technology
FY2004	ARGCS	Agile Rapid Global Combat Support
FY2004	CORSOM	Coalition Reception Staging & Onward Movement
FY2004	COSINE	Coalition Shared Intel Network Environment - DEMO COMPLETE
FY2004	FTTS	Future Tactical Truck System
FY2004	JPADS	Joint Precision Airdrop System
FY2004	J-USC2	Joint Unmanned Sys Common Control
FY2004	MANPACK	MANPACK
FY2004	MAJIIC	Multi-Sensor Aerospace/Ground Joint ISR Interoperability Coalition
FY2004	MAGNUM	MAGNUM
FY2004	PLATO	Protected Landing and Take-Off
FY2004	PSYOP	Psychological Operations (PSYOP) Global Reach
FY2004	TEBO	Theater Effects Based Operations
FY2003	AJCN	Adaptive Joint C4ISR Node - DEMO COMPLETE
FY2003	CB2	Counter Bomb/ Counter Bomber

Year	ACTD Acronym	ACTD Name
FY2003	DCS	Deployable Cargo Screening
FY2003	FOPEN	Foliage Pen Syn App Rad
FY2003	GPE	Gridlock - RESID COMPLETE
FY2003	HAA	High Altitude Airship
FY2003	JBFSA	Joint Blue Force Situational Awareness - DEMO COMPLETE
FY2003	MS	Midnight Stand (prev. IT) - DEMO COMPLETE
FY2003	NVCUA	Night Vision Cave & Urban Assault - DEMO COMPLETE
FY2003	OW	Overwatch
FY2003	TIM	Tactical IFSAR Mapping
FY2003	TSV	Theater Support Vessel
FY2003	TTD	Tunnel Target Defeat
FY2003	UR	Urban Recon
FY2002	ADS	Active Denial System
FY2002	ADW	Agent Defeat Warhead
FY2002	AT	Agile Transportation
FY2002	BS	Boundary Step - RESID COMPLETE
FY2002	CIA COP	Coalition Information Assurance Common Operational Picture
FY2002	CASPOD	Contamination Avoidance at Seaports of Debarkation - DEMO COMPLETE
FY2002	EUAV	Expendable Unmanned Aerial Vehicle - RESID COMPLETE
FY2002	HLSC2	Homeland Security Command and Control - DEMO COMPLETE
FY2002	HYCAS	Hyperspectral Collection and Analysis
FY2002	JDSR	Joint Distance Support & Response - DEMO COMPLETE
FY2002	JEOD-KTOD	Joint Explosive Ordnance Disposal - DEMO COMPLETE
FY2002	LASER	Language and Speech Exploitation Resources - DEMO COMPLETE
FY2002	MAV	Micro Air Vehicle
FY2002	PathF	Pathfinder
FY2002	SIGINT	SIGINT Processing

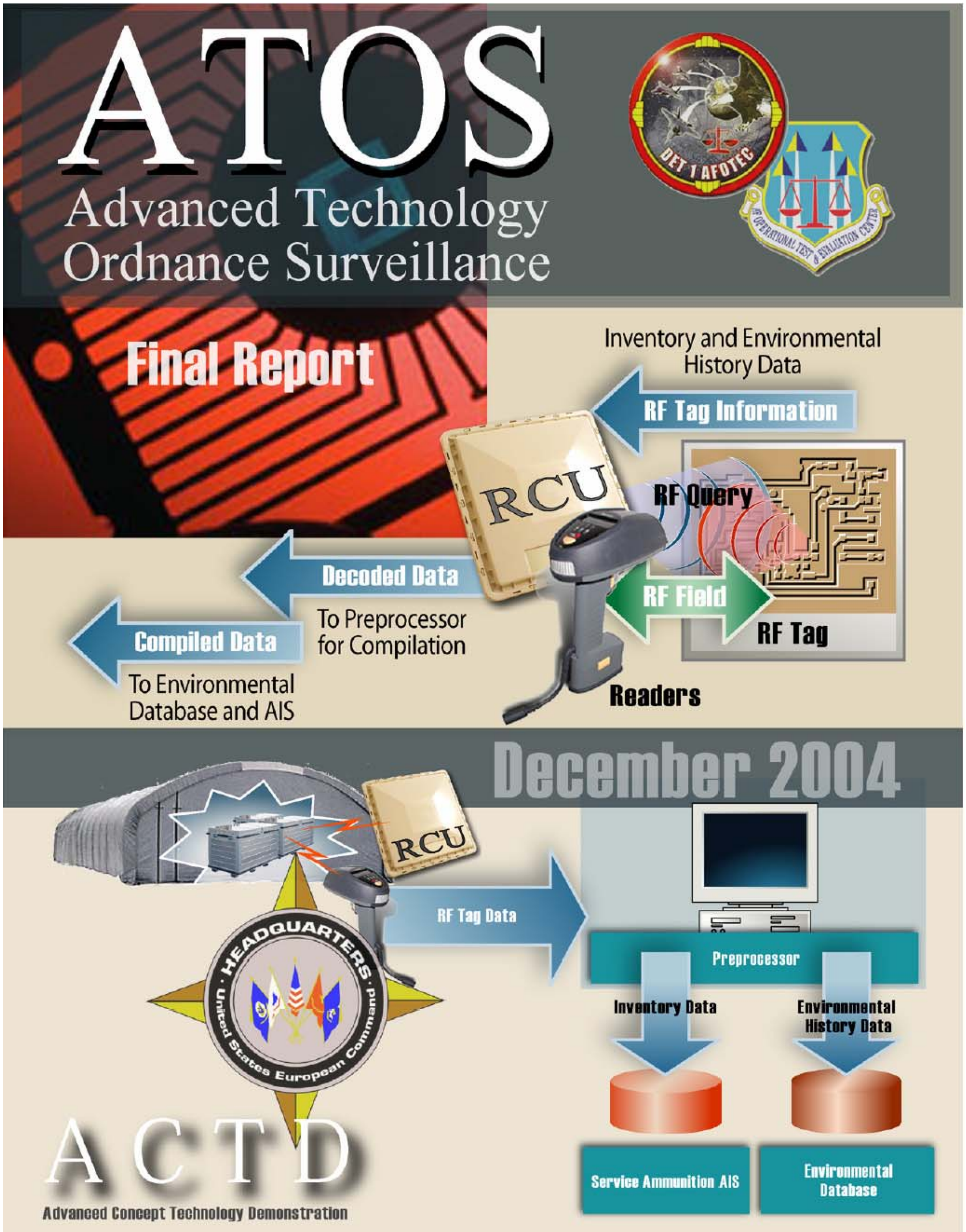
Year	ACTD Acronym	ACTD Name
FY2002	Space-Based MTI	Space-Based MTI
FY2002	SPARTAN	SPARTAN
FY2002	TB	Thermobarics - DEMO COMPLETE
FY2001	ANID	Active Network Intrusion Defense - DEMO COMPLETE
FY2001	ABA	Adaptive Battlespace Awareness - RESID COMPLETE
FY2001	ATL	Advanced Tactical Laser
FY2001	ATOS	Advanced Technology Ordnance Surveillance - RESID COMPLETE
FY2001	ACMD	Area Cruise Missile Defense - RESID COMPLETE
FY2001	CCID	Coalition Combat ID - DEMO COMPLETE
FY2001	CTL	Coalition Theater Logistics - RESID COMPLETE
FY2001	CAPS	Coastal Area Protection System - RESID COMPLETE
FY2001	HSKT	Hunter Standoff Killer Team
FY2001	JAC	Joint Area Clearance - RESID COMPLETE
FY2001	LEWK	Loitering Electronic Warfare Killer
FY2001	NCCT	Network-Centric Collaborative Targeting (formerly NCCIS&R) - DEMO COMPLETE
FY2001	PRESS	Personnel Recovery Extraction Survivability aided by Smart Sensors
FY2001	TACMS-P	Tactical Missile System Penetrator - RESID COMPLETE
FY2001	TIPS	Theater Integrated Planning System - DEMO COMPLETE
FY2000	CINC 21	CINC 21 - RESID COMPLETE
FY2000	CAESAR	Coalition Aerial Surveillance and Reconnaissance - RESID COMPLETE
FY2000	C/NOFS	Comm/Nav Outage Forecast System
FY2000	COMWX	Computerized Operational MASINT Weather - RESID COMPLETE
FY2000	*Umbrella)*	Content-Based Info Security
FY2000	GMSIS	Global Monitoring of Space ISR Systems - RESID COMPLETE
FY2000	GAPS	Ground-to-Air Passive Surveillance - RESID COMPLETE
FY2000	JISR	Joint Intelligence, Surveillance & Reconnaissance - RESID COMPLETE

Year	ACTD Acronym	ACTD Name
FY2000	MLAS	Multiple Link Antenna System - RESID COMPLETE
FY2000	QBolt	Quick Bolt - RESID COMPLETE
FY2000	RestOps	Restoration of Operations - RESID COMPLETE
FY2000	TASC	Tri-Band Antenna Signal Combiner - RESID COMPLETE
FY1999	BDA in JTT	Battle Damage Assessment in the Joint Targeting Toolbox - RESID COMPLETE
FY1999	CACE	Coherent Analytical Computing Environment - RESID COMPLETE
FY1999	COSMEC	Common Spectral MASINT Exploitation - RESID COMPLETE
FY1999	CEASE II	Compact Environmental Anomaly Sensor II - RESID COMPLETE
FY1999	FMP/D	Force Medical Protection / Dosimeter - RESID COMPLETE
FY1999	HICIST	Human Intelligence & Counterintelligence Support Tools - RESID COMPLETE
FY1999	JMOT	Joint Medical Operations / Telemedicine - RESID COMPLETE
FY1999	JTL (JLCP)	Joint Theater Logistics - RESID COMPLETE
FY1999	PRMS	Personnel Recovery Mission Software - RESID COMPLETE
FY1999	SUL	Small Unit Logistics - RESID COMPLETE
FY1999	TAMDI	Theater Air & Missile Defense Interoperability - RESID COMPLETE
FY1998	ACOA	Adaptive Course of Action - RESID COMPLETE
FY1998	C4I for CW	C4I for Coalition Warfare - RESID COMPLETE
FY1998	HPM	High Power Microwave - RESID COMPLETE
FY1998	IA:AIDE	Info Assurance: Automated Intrusion Detection Environment - RESID COMPLETE

Year	ACTD Acronym	ACTD Name
FY1998	JBREWS	Joint Biological Remote Early Warning System - RESID COMPLETE
FY1998	JCSE	Joint Continuous Strike Environ. - RESID COMPLETE
FY1998	JMLS *(JLOTS)*	Joint Modular Lighter System - RESID COMPLETE
FY1998	LOSAT	Line of Sight Anti-Tank - RESID COMPLETE
FY1998	Link-16	Link-16 - RESID COMPLETE
FY1998	MDITDS	Migration Defense Intelligence Threat Data System - RESID COMPLETE
FY1998	PTI	Precision Targeting Identification - RESID COMPLETE
FY1998	SBSSO	Space Based Space Surveillance Operations - RESID COMPLETE
FY1998	TPSO	Theater Precision Strike Ops - RESID COMPLETE
FY1998	UGS	Unattended Ground Sensors - RESID COMPLETE
FY1997	Chem Add-On	Chemical Add-On to Bio Detection - RESID COMPLETE
FY1997	Cons Mgt	Consequence Management - RESID COMPLETE
FY1997	CP II	Counterproliferation II - RESID COMPLETE
FY1997	ELB/JTFW	COMPLETE
FY1997	IOPT *(IWPT)*	Info. Operations Planning Tool - RESID COMPLETE
FY1997	ICM	Integrated Collection Mgt. - RESID COMPLETE
FY1997	JAHUMS	Joint Advanced Health and Usage Monitoring System - DEMO COMPLETE
FY1997	MOUT *(MOBA)*	Military Ops in Urban Terrain - RESID COMPLETE
FY1997	RTV *(RBV)*	Rapid Terrain Visualization - RESID COMPLETE
FY1996	ABP Bio Det	Airbase/Port Biological Detection - RESID COMPLETE
FY1996	BADD	COMPLETE

Year	ACTD Acronym	ACTD Name
FY1996	CID	Combat Identification - RESID COMPLETE
FY1996	CVS	Combat Vehicle Survivability - RESID COMPLETE
FY1996	CS	Counter Sniper - RESID COMPLETE
FY1996	CP I	Counterproliferation I - RESID COMPLETE
FY1996	JL	Joint Logistics - RESID COMPLETE
FY1996	MALD *(SENGAP)*	Miniature Air-Launched Decoy - RESID COMPLETE
FY1996	NAVWAR	Navigation Warfare - RESID COMPLETE
FY1996	SAIP	Semi-Automated IMINT Processing - RESID COMPLETE
FY1996	THEL	Tactical High Energy Laser - DEMO COMPLETE
FY1996	TUAV *(Outrider)*	Tactical UAV - RESID COMPLETE
FY1995	AJP	Advanced Joint Planning - RESID COMPLETE
FY1995	BPI	Boost Phase Intercept - RESID COMPLETE
FY1995	CMD	Cruise Missile Defense, Phase 1 - RESID COMPLETE
FY1995	HAE UAV	High Alt Endurance UAVs - RESID COMPLETE
FY1995	JCM	Joint Countermine - RESID COMPLETE
FY1995	*(VERTREP)*	Low Life Cycle Cost Helo - RESID COMPLETE
FY1995	MAE *(Predator)*	Med Alt Endurance UAV - RESID COMPLETE
FY1995	PSTS	Precision SIGINT Targeting Sys. - RESID COMPLETE
FY1995	P/RC-MRL	Precision/Rapid Counter-MRL - RESID COMPLETE
FY1995	RFPI *(H-SOR, EFOGM)*	Rapid Force Projection Initiative - RESID COMPLETE
FY1995	(JASP)	Synthetic Theater of War - RESID COMPLETE

APPENDIX B. ATOS MUA FINAL REPORT



Detachment 1

ADVANCED TECHNOLOGY ORDNANCE SURVEILLANCE

ADVANCED CONCEPT TECHNOLOGY DEMONSTRATION

MILITARY UTILITY ASSESSMENT

FINAL REPORT

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Commander, Detachment 1 AFOTEC

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ADVANCED TECHNOLOGY ORDNANCE SURVEILLANCE

ADVANCED CONCEPT TECHNOLOGY DEMONSTRATION

MILITARY UTILITY ASSESSMENT

FINAL REPORT

US Air Force Operational Test and Evaluation Center
Detachment 1

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ADVANCED TECHNOLOGY ORDNANCE SURVEILLANCE

ADVANCED CONCEPT TECHNOLOGY DEMONSTRATION

MILITARY UTILITY ASSESSMENT

FINAL REPORT

US Air Force Operational Test and Evaluation Center
Detachment 1

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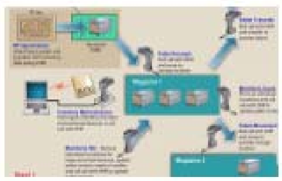
The Advanced Technology Ordnance Surveillance Advanced Concept Technology Demonstration was intended to demonstrate an automated system that could be used to enhance the management of munitions and provide near real-time environmental surveillance data on stored critical munitions. This document describes the results, conclusions, and recom-



Detachment 1 Air Force Operational Test and Evaluation Center conducted a military utility assessment to determine the capability of the Advanced Technology Ordnance Surveillance system to provide reliable and accurate environmental surveillance data on tagged munitions pallets and to support munitions management tasks. Data were collected from a technical evaluation at the Naval Surface Warfare Center, Indian Head, MD, and from three operational demonstrations at Miesau Army Ammunition Depot, Miesau, Germany; Crane Army Ammunition Activity Depot, Crane, IN; and Norfolk Naval Station, Norfolk, VA, on two US Navy vessels. These events were conducted between March 2003 and August 2004.

The Technical Manager provided 19 detailed scenarios that were used to assess how well the Advanced Technology Ordnance Surveillance system supported the munitions management tasks at strategic and tactical depots. Objective data were collected to evaluate system performance in a realistic operational environment and to determine if the munitions system met US European Command functional requirements. Questionnaires were provided to the warfighters to capture their opinions of the system's usability and utility.

The Advanced Technology Ordnance Surveillance system demonstrated the capability to enhance the munitions management logistics processes and provide the warfighter with environmental surveillance information on tagged munitions pallets. Questionnaire responses and comments from warfighters indicated the system was effective in providing environmental surveillance information on tagged munitions pallets and enhanced the munitions management tasks.

The Advanced Technology Ordnance Surveillance system demonstrated military utility, but could be improved by enhancing handheld reader data transfer capability to support up to 1,000 records, modifying the radio frequency tag so munitions quality assurance data can be entered, and evaluating the interoperability of the system with service ammunition automated information systems.

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EXECUTIVE SUMMARY

The purpose of the Advanced Technology Ordnance Surveillance (ATOS) Advanced Concept Technology Demonstration (ACTD) was to demonstrate an automated system that was designed to provide near-real time environmental data on critical munitions and use the latest in automatic identification technologies (AIT) and micro-electrical mechanical sensors (MEMS) to enhance munitions management. This document presents the results, conclusions, and recommendations derived by Detachment 1 (Det 1) Air Force Operational Test and Evaluation Center (AFOTEC) for the military utility assessment (MUA) of ATOS.

The ATOS MUA includes results obtained during a technical evaluation (TECEVAL) and three operational demonstrations conducted from March 2003 to August 2004 at four locations. The TECEVAL was held at Naval Sea Systems Command (NAVSEA), Indian Head, MD, between 28 March 2003 and 16 July 2004 to assess ATOS performance in a controlled laboratory environment. The Det 1 AFOTEC assessment team collected performance data to augment data collected during the operational demonstrations. The first operational demonstration was held at Miesau Army Munitions Depot, Miesau, Germany from 9 to 23 March 2004 and assessed ATOS's capability to support distribution of munitions from a theater-level depot. The second operational demonstration was held at Crane Army Ammunition Activity (CAAA), Crane, IN, from 12 to 23 April 2004 and assessed ATOS's capability to support wholesale distribution of munitions from a strategic-level depot. The third operational demonstration was held at Norfolk Naval Station, Norfolk, VA, and consisted of two events. The first event was held on the United States Ship (USS) Ponce from 12 to 23 April 2004. The second event was conducted in two parts: the first part was held on the pier where the USS Harry S. Truman was docked from 17 to 19 August 2004, and the second part was held on the USS Harry S. Truman from 23 to 27 August 2004. These three maritime events assessed ATOS's capability to support munitions distribution aboard naval vessels.

As directed by US European Command (USEUCOM), the MUA assessed ATOS' capability to support environmental surveillance and munitions management. The environmental surveillance focused on the radio frequency (RF) tag's capability to collect and store temperature and relative humidity (RH) data. The munitions management focused on ATOS' capability to support and enhance munitions management tasks (pallet receipt, inventory maintenance, pallet movement, pallet issue, pallet transfer, and munitions quality assurance [QA]). In addition to the USECOM functional requirements, Det 1 AFOTEC characterized ATOS system capabilities in terms of training, component ruggedness, power requirements, and installation requirements. A security assessment was planned but not performed due to lack of security expertise from the operators.

The ATOS system demonstrated potential military utility by providing the warfighter near-real time environmental surveillance data and supporting five out of the six munition management tasks during the demonstrations. The RF tags measured and recorded temperature and RH throughout the demonstrations. Although the RF tags performed well during the demonstrations, some of the warfighters expressed concern about the cost of the RF tag and the fact that they were not designed to be reusable on other munitions pallets. Also, the gravity-shock (G-shock) sensor on the RF tag must be further developed and tested. The warfighters indicated that ATOS enhanced munitions management tasks and that it was easy to install, user friendly, easy to learn, and easy to operate. Data transfer problems between the handheld reader (HHR) and the preprocessor (PP) diminished effectiveness of pallet receipt and inventory maintenance tasks. The RF tag record requires additional fields to accommodate tracking of QA inspections. The ATOS system demonstrated good support for pallet movement, issue, and transfer tasks.

System recommendations fall into two categories: environmental surveillance and munitions management. For the former, RF tags require three upgrades: time/date stamp of temperature and RH readings that exceed limits, reusable tags, and further development of G-shock sensors. For munitions management, recommendations focus on data transfer capabilities and the addition of RF tag fields to allow tracking of QA inspections.

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SITUATION

Background

The effective management of the large Department of Defense (DoD) munitions stockpile has long been hindered by labor-intensive inventory methods and stockpile inaccuracies. The current process involves manual data entry using an inventory sheet to track and monitor the flow of munitions. The loss of asset visibility due to stockpile inaccuracies also creates a host of problems for the acquisition manager, logistician, storage custodian, and the warfighter. Overall mission readiness is degraded because needed munitions either cannot be located, or when located, the serviceability cannot be determined because the current surveillance methods do not provide the critical environmental information needed to determine munitions serviceability. Storage conditions, particularly temperature and RH profiles, and G-shock can have significant impacts on munitions' safety and reliability. By utilizing the latest in AIT and MEMS, the warfighter should have a capability that provides near-real-time environmental data and automated support for managing the complex DoD munitions stockpile.

The ATOS ACTD is a Department of the Navy ACTD sponsored by USEUCOM. USEUCOM requested Det 1 AFOTEC to conduct a MUA of the ATOS system. This report describes the assessment of ATOS performance using data from the TECEVAL and operational demonstrations. It includes the assessment methodology, data collection methods, data analysis, and MUA results.

System Description

The ATOS system is an automated system that provides the warfighter a capability to collect environmental data in near-real-time and supports munitions management tasks on stored munitions pallets. The ATOS system consists of six major components: RF tag, HHR, Reader Control Unit (RCU), PP, environmental database (EDB), and an interface to service ammunition automated information system (AIS). In addition, radio frequency extenders (RFE) are used to enhance RF coverage inside enclosed magazines or depots. The EDB and interface to Service Ammunition AIS were not available to demonstrate during the ACTD. **Figure 1** shows connectivity for the ATOS system components.

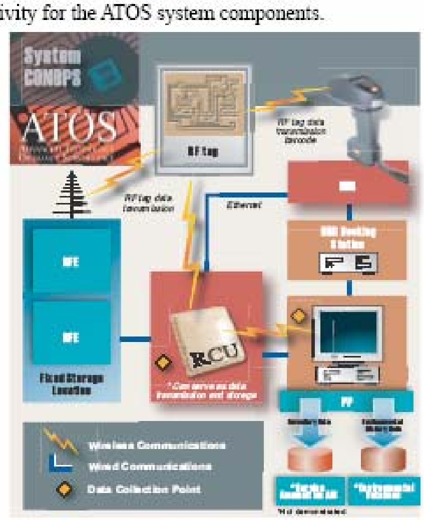

Figure 1. ATOS System: ATOS was designed to provide environmental surveillance data and to support munitions management tasks.

The RF tag is a small enclosure attached to a munitions pallet using an RF tag holder. The RF tag contains temperature, RH, and G-shock sensors. The temperature and RH sensors collect environmental data according to a defined schedule (every 60 minutes during the ACTD). The RF tag also has a receiver, transmitter, and non-volatile memory to receive, transmit, and store unique asset information and environmental data.

The HHR is a portable wireless barcode scanning device with the capability to read and write asset data to and from the RF tags and read linear and 2-dimensional barcodes. Using a keypad and touch screen, the users can upload and download asset information to and from the RF tags using a function called roll call, which queries the RF tag to identify itself and provide any changes to asset and environmental data. Data are stored in the HHR as transaction records until they are transferred to the PP for analysis and storage. The HHR can also retrieve stored RF tag data from the RCU using an Ethernet cable. The HHR uses a Windows Pocket Personal Computer operating system, which is a commercial off-the-shelf technology (COTS) software.

The RCU is a fixed RF reader that collects asset and environmental data from the RF tags. The RCU is powered by 24 volts direct current (VDC) and can be mounted inside a munitions magazine. Depending on the size of the magazine, RFEs are connected in series with the RCU to achieve optimal RF transmission coverage. The RCU obtains data from the RF tags using a function called interrogation, which consists of two independent reads (short and long). The short read determines the number of RF tags detected, RF tag identification (ID), Department of Defense Identification Code (DODIC), National Stock Number (NSN), consignee, any environmental sensor flags, and a low battery flag. The time duration for a short read depends upon the number of RFEs connected in series with the RCU, the number of RF tags detected inside the storage facility, and the type of material (wooden crates and aluminum pallets) on which the RF tags were attached. The long read downloads the remaining asset information and environmental data. The duration of a long read can take hours to days depending on the number of RF tags being interrogated. The RCU serves as a long-term data storage unit for receiving and storing interrogated RF tag data. The RCU stores these data until the PP commands it to transfer the data via a wireless local area network (WLAN), local area network (LAN), serial cable connection with the HHR. The RCU has no direct user interface (i.e., no keyboard or display).

The PP is an interactive command and control system designed to retrieve RF tag data from the RCU and HHR. The PP is typically located in the central work area. Munitions information is formatted and passed from the PP to service ammunition AISs (e.g., Retail Ordnance Logistics Management System for US Navy local and theater inventory management of munitions) and the EDB. Munitions experts and analysts can use the EDB to evaluate munitions performance fluctuations due to environmental changes.

System Concept

The ATOS system provides two key capabilities to manage the DoD munitions inventory process: environmental surveillance and munitions management. To perform the environmental surveillance capability, the RF tag collects and records temperature and RH data from tagged munitions pallets. For the ACTD, the RF tags were programmed to collect and record temperature and RH data every 60 minutes. The G-shock sensor was not demonstrated for this assessment. The environmental data collected by the RF tags were downloaded to the PP via RCU or HHR. **Table 1** describes the munitions management tasks, **Figure 2** graphically displays how ATOS automates these tasks, and **Table 2** describes the ATOS automation of each task.

Table 1. Munitions Management Tasks: These six tasks form the foundation for inventory management of munitions.

Munitions Management Tasks	
Name	**Task**
Pallet Receipt	Receive incoming munitions pallets, move them to an initial storage location, and add them to the inventory.
Inventory Maintenance	Maintain inventory information on munitions pallets.
Pallet Movement	Move munitions pallets from one location to another within the same depot.
Pallet Issue	Issue one or more individual munitions from pallets to local field units and update inventory.
Pallet Transfer	Ship munitions pallets from one depot to another and remove munitions pallets from the origination inventory.
Munitions QA	Remove one or more individual munitions from pallets for inspection/maintenance, update pallet inventory return individual munitions to the same pallet after inspection/maintenance, and update the inventory.

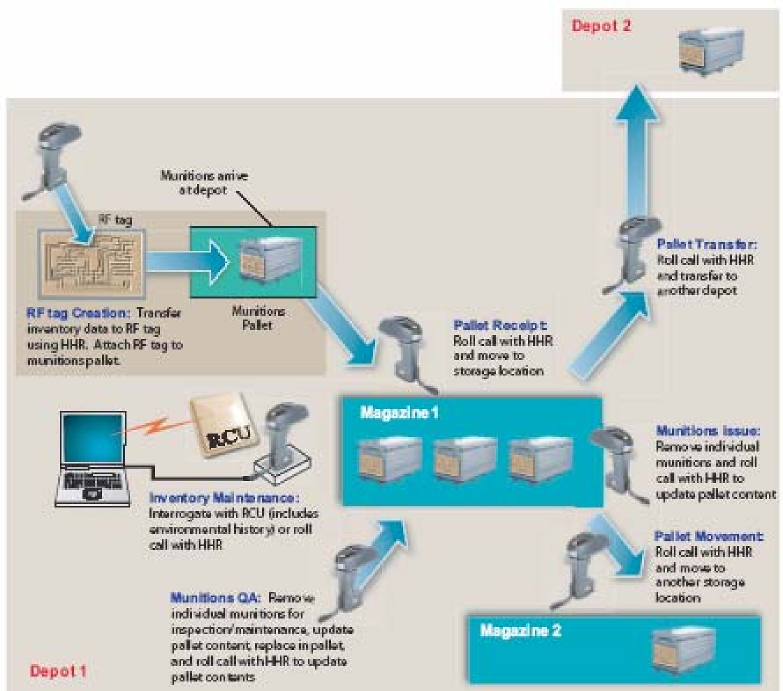

Figure 2. Automated Munitions Management Functions: ATOS is designed to automate the current labor-intensive munitions inventory management processes by supporting six munitions management tasks.

Table 2. Munitions Management Tasks using ATOS System: ATOS system automates the currently labor-intensive munitions management processes.

Munitions Management Processes using ATOS	
Name	**Process**
Pallet Receipt	When munitions arrive at a depot, munitions or logistics personnel attach RF tags to munitions pallets and populate RF tags with asset information for each munitions pallet using the HHR. Next, tagged munitions pallets are receipted and the asset information is stored on the HHR as a transaction record. Tagged munitions pallets are moved to a storage location where the RCU retrieves the asset information and the latest environmental data from the munitions pallets. The RCU updates and stores the RF tag data until the PP commands it to transfer the data via WLAN, LAN, or the HHR serial port. The PP reconciles the transaction records from the HHR and RCU data, updates the inventory list, and graphically displays the data on the computer screen.
Inventory Maintenance	The RCU maintains the munitions inventory through periodic interrogations of the RF tags. If the RCU encounters a new or missing RF tag, it sends a flag to the PP. When conducting inventory tasks using an HHR, the ATOS operator first downloads the inventory list from the PP to the HHR. The operator then takes the HHR to the magazine. The HHR queries the RF tags and reconciles the inventory list with the tagged munitions pallets inside the magazine. Any new or missing RF tags are flagged by the HHR and associated data are later transferred to the PP. The operator takes appropriate actions to resolve any flags that were sent to the PP from the HHR or RCU. Throughout this process, the RF tags continually collect and store environmental data.
Pallet Movement	Tagged munitions pallets are moved from one location to another within the same depot. The operator uses the HHR to update the RF tag location information. On the next interrogation, the RCU automatically updates location data on the PP inventory list.
Pallet Issue	The operator issues one or more individual munitions items from tagged munitions pallets to a local field unit and uses the HHR to update the munitions count on the RF tag. The RCU captures the munitions count change and updates the PP inventory list.
Pallet Transfer	The operator ships a tagged munitions pallet to a location outside of the depot, using the HHR to document the transfer. The operator uses the HHR to download the latest asset information, environmental data, and any alarm flags. The HHR is docked to the PP and data are transferred to the PP. The RF tag ID number is removed from the inventory list and the data are archived. The PP automatically updates the inventory records of the losing depot when the HHR is docked to the PP. Munitions pallets are not tracked while in transit between depots, but the RF tags will continue to collect environmental data, which is transferred to the PP at the final destination.
Munitions QA	The operator removes one or more individual munitions items from tagged munitions pallets for inspection/maintenance. QA personnel use the HHR to update the pallet condition code and history to reflect the status of the individual munitions items and what QA actions were taken upon its return to the inventory. The RCU captures the updated information and transfers it to the PP. The PP then reconciles the RCU and HHR data and updates the inventory list. This function was not supported during the ACTD since the RF tag lacked sufficient fields and tracking capability to record inspection and maintenance performed on individual munitions.

Assessment Overview

Objective and subjective data were collected from the TECEVAL and three operational demonstration events between March 2003 and August 2004 to assess the ATOS system military utility in providing environmental data and automating the munitions management tasks. **Table 3** describes the TECEVAL and operational demonstrations used to assess the ATOS system.

Table 3. MUA Demonstration Schedule: System performance was assessed during the TECEVAL and three operational demonstrations.

Demonstration Schedule			
Demonstration	**Date**	**Location**	**Purpose**
TECEVAL	28 March 2003 16 July 2004	NAVSEA, Indian Head, MD	Demonstrate system performance in a controlled laboratory environment.
OCONUS Demonstration	9-23 March 2004	Miesau Army Munitions Depot, Miesau, Germany	Demonstrate system performance in a theater-level depot.
CONUS Demonstration	12-23 April 2004	CAAA, Crane, IN	Demonstrate system performance in a strategic-level depot.
Maritime Demonstration	6-9 July 2004 (Part 1)	Norfolk Naval Station (combat logistics ship)	Demonstrate HHR capability to conduct the logistics tasks without having the RCU installed inside a shipboard magazine.
	17-19 August 2004 (Part 2a)	Norfolk Naval Station (aircraft carrier)	Assess RF tag ruggedness on munitions pallets transported from CAAA to Norfolk Naval Station.
	23-27 August 2004 (Part 2b)	Norfolk Naval Station (aircraft carrier)	Demonstrate system performance in a shipboard magazine.

Outside the Continental United States (OCONUS)
Continental United States (CONUS)

Limitations and Constraints

While a thorough assessment of the ATOS system was desirable, it was constrained by two known limitations listed in **Table 4** and five additional limitations listed in **Table 5** encountered during the demonstration execution.

Table 4. Original Limitations and Constraints: These two limitations were well known prior to assessment team deployment.

Original Limitations and Constraints		
Limitation	**Impact**	**Action/Recommendation**
Service Ammunition AIS and EDB not demonstrated.	Unable to assess the interoperability between the PP and Service Ammunition AIS and EDB.	Conduct further, more detailed testing during formal acquisition.
RF tags were placed on the outside of the munitions pallet containers.	Unable to record environmental readings of the inside of munitions pallet containers or on individual munitions when they were removed from the pallet.	Attach RF tags to inside of individual munitions containers. Develop environmental sensors that are embedded in the munitions.

Table 5. Additional Limitations and Constraints: Five additional limitations and constraints were identified during the demonstrations.

Additional Limitations and Constraints		
Limitation	**Impact**	**Action/Recommendation**
RF tags do not collect date/time stamp information.	Unable to correlate temperature and RH measurements to a specific time.	Used TECEVAL data to verify sensor accuracy. Compared baseline temperature and RH with RF tag histogram.
No QA personnel available during operational demonstrations.	No assessment of munitions QA task (only review of ATOS specifications).	Conduct QA testing in the future.
No military airlift demonstration and no removal of RF tags during maritime demonstration.	Limited assessment of ATOS component ruggedness.	Conduct further ruggedness testing in the future.
Limited visibility into RCU interrogation performance.	Difficult to verify number of RF tags detected within the stated requirements of 145 and 215 minutes.	Used the TM-provided data from the RCU data/ error logger to assess RCU interrogation data.
No SME assessment of ATOS network security.	Unable to assess ATOS network	Request Joint Information Operation Center conduct a network security assessment on ATOS.

SME - subject matter expert
TM - technical manager

Participating Agencies

US European Command

The USEUCOM is a unified combatant command whose mission is to maintain ready forces to conduct the full spectrum of military operations, enhance transatlantic security through support to the North Atlantic Treaty Organization, promote regional stability, and advance US interests in Europe, Africa, and the Middle East. As the ACTD sponsor, the USEUCOM provided the Operational Manager (OM), developed operational requirements for the employment of the ATOS program technologies, developed the concept of operations (CONOPS), and supported plans for the demonstrations.

Joint Munitions Command

The Joint Munitions Command (JMC) serves as the Army's single manager for producing, storing, maintaining, and demilitarizing conventional ammunition for all military Services. The JMC developed the Demonstration Master Plan, which articulated the ACTD demonstration strategy used to evaluate the ATOS system. Additionally, the JMC provided the Demonstration Manager, assisted USEUCOM in developing the ATOS system CONOPS and support plans, and provided operators for the CONUS demonstration.

Naval Sea Systems Command

The NAVSEA, Naval Surface Warfare Center (NSWC), Indian Head Division, serves as the leading research and development organization specializing in developing products for special weapons, explosives, pyrotechnics, and ordnance handling. Its primary mission is to transform military requirements into naval capabilities. The NAVSEA was responsible for the program management of the ATOS ACTD. During the MUA, the NAVSEA provided training resources, the support associated with the development and demonstration of ATOS system technologies, technical support for ACTD demonstrations, and the ACTD TM. NAVSEA also provided the Transition Manager, who is responsible for transitioning the technology to the warfighter.

US Air Forces in Europe

The mission of US Air Forces in Europe is to plan, conduct, and coordinate offensive and defensive air operations in the European area of responsibility (AOR). The US Air Forces in Europe provided operators for the OCONUS demonstration.

US Army, Europe

The mission of US Army, Europe is to maintain forward-deployed combat forces trained and ready to conduct and support joint and multinational operations and conduct engagement activities to protect US interests in the European AOR. The US Army, Europe provided operators for the OCONUS demonstration.

US Atlantic Fleet

The US Atlantic Fleet provides fully trained, combat ready forces to support US and North Atlantic Treaty Organization commanders in regions of conflict throughout the world. From the Adriatic Sea to the Arabian Gulf, Atlantic Fleet units respond to National Command Authority tasking. The US Atlantic Fleet provided operators for the maritime demonstrations.

Det 1 AFOTEC

The Det 1 AFOTEC mission is to provide independent and tailored demonstration and utility assessments of new technologies in support of Combatant Commander and other government decision makers for the purpose of rapidly fielding warfighting capabilities. During this ACTD, Det 1 AFOTEC was the independent assessment agency for evaluating the military utility of the ATOS system. Det 1 AFOTEC refined scenarios, developed the MUA assessment methodology, and wrote this final MUA report.

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Execution

Methodology

The initial assessment methodology was based on characterizing the military utility of individual ATOS components. Det 1 AFOTEC developed critical operational issues (COI), measures of effectiveness (MOE), and measures of performance (MOP) based on the requirements stipulated in the USEUCOM Functional Requirements Document (FRD). **Table 6** lists the COIs and MOEs from the approved assessment execution document. During the Miesau demonstration, USEUCOM directed Det 1 AFOTEC to assess ATOS system capabilities in support of environmental surveillance and munitions management. The details on munitions management tasks were not available in time to revise the COIs, MOEs, and MOPs. Therefore, the assessment team correlated existing component-level measures to environmental surveillance and munitions management capabilities. As a result, MOEs 1.2 and 1.6 address environmental surveillance, MOEs 2.5 through 2.8 characterize the ATOS system, and the remainder of the MOEs address munitions management. **Appendix B** provides the correlation of the MOEs to environmental surveillance and individual munitions management tasks. A complete list of MOP results is contained in **Appendix D**, while **Appendix E** correlates MOP results with USEUCOM FRD requirements.

Table 6. COIs and MOEs: Two COIs and associated MOEs provided a framework to assess the military utility of the ATOS system

COIs and MOEs		
COIs	**MOEs**	
1. Does ATOS support asset visibility, accountability, and serviceability for munitions?	1.1	Capability of ATOS system to provide container location data.
	1.2	Capability of ATOS system to accurately report and maintain environmental data on containers.
	1.3	Capability of ATOS RF tags to communicate with RCU or HHR.
	1.4	Capability of ATOS HHR and RCU to communicate and transfer data to PP.
	1.5	Capability of ATOS PP to interoperate with Service Ammunition AIS.
	1.6	Capability of ATOS PP to interoperate with EDB.
	1.7	Characterization of network bandwidth connectivity to ATOS PP.
	1.8	Capability of ATOS system to protect data.
	1.9	Capability of ATOS system to provide sufficient data storage.
	1.10	Characterization of ATOS RCU antenna coverage.
	1.11	Capability of ATOS RCU to detect RF tags at initial startup.
	1.12	Usability of ATOS HHR input devices.
	1.13	Capability of ATOS HHR to create RF tags and barcodes.
2. Is ATOS supportable for military operations?	2.1	Reliability of ATOS RF tag attachment.
	2.2	Usability of ATOS HHR and RCU.
	2.3	Usability of ATOS PP.
	2.4	Ease of configuraton for ATOS components.
	2.5	Adequacy of ATOS training.
	2.6	Adequacy of ATOS componet ruggedness.
	2.7	Supportability of ATOS power requirements.
	2.8	Supportability of ATOS installation.

Data Collection and Analysis

The assessment team collected both objective and subjective data during the operational demonstrations using the scenarios described in **Appendix C**. Det 1 AFOTEC used Microsoft Excel to store and manage data collected during the operational demonstration events.

Objective Data

Objective data came from the following sources:

- Assessment team observations (initial RF tag detection, RF tag communications with HHR/RCU/PP)
- Kestrel 4000 portable weather station data (baseline temperature and RH data during operational demonstrations)
- ATOS performance data (RCU performance logs, environmental histogram data)
- Laboratory instrumentation at NSWC during the TECEVAL (baseline temperature and RH data, battery test, RCU antenna coverage, noise vibration data)
- Extracts from RCU data (interrogation time cycle, number of RF tags detected, PP communications with HHR/RCU)

Subjective Data

Subjective data consisted of warfighter and SME feedback (documented on questionnaires) and assessment team comments (documented on observation logs). The Det 1 AFOTEC Test Director observed ATOS training and the lead analyst observed the ATOS installation. Both the Test Director and lead analyst observed warfighters during operational demonstration scenarios. Questionnaires were tailored and administered to SMEs based on their area of expertise (operator, munitions, logistics, or security). **Appendix F** provides a complete listing of questionnaire results from all operational demonstrations.

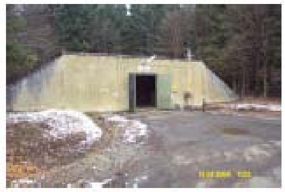
ATOS Events

Technical Evaluation

The purpose of the TECEVAL was to collect performance data in a controlled laboratory environment. The TECEVAL consisted of four visits to the NSWC, Indian Head, MD between 28 March 2003 and 16 July 2004. During these visits, the assessment team collected performance data on the RF tag environmental sensors, antenna coverage range data, and changes to the PP software. Two end-to-end system tests were conducted to ensure ATOS would be ready to support the OCONUS demonstrations. A test of ATOS autonomous operation was conducted from 12-16 July 2004.

OCONUS Demonstration

The purpose of the OCONUS demonstration was to collect performance data at the largest theater-level munitions storage area in Europe. The OCONUS operational depot demonstration was conducted at Miesau Army Ammunition Depot at Miesau, Germany from 9 to 23 March 2004. During the first week, the assessment team observed user training, as well as installation of the ATOS components in a 60 x 40 x 15 foot earth-covered magazine and a 70 x 200 foot open storage area called the ammunition supply point (ASP) (see **Figure 3**). After the installation, the TM placed 200 RF tags at both locations. The assessment team collected observation data and administered training questionnaires during the first week of the demonstration. During the second week, the warfighters performed the scenarios listed in Appendix C. The assessment team collected observation data; administered operator, logistics, and munitions questionnaires; and collected RCU performance data. The assessment team was not able to collect theater-level QA data because a QA participant was not available to support the demonstration.



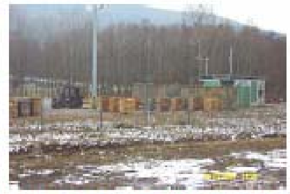


Figure 3. Miesau Earth-Covered Magazine and ASP: The OCONUS demonstration provided two distinct environments for the ATOS system.

CONUS Demonstration

The purpose of the CONUS demonstration was to collect performance data at a strategic wholesale depot that receives and ships conventional munitions to the Army and Navy worldwide. The CONUS demonstration was conducted at two test sites at the CAAA depot at Crane, IN during 12 to 23 April 2004. The assessment team observed user training, as well as installation of the ATOS components (six RFEs, RCU, PP, and WLAN) in a 100 x 50 x 10 foot earth-covered magazine (see **Figure** 4). This demonstration site used a WLAN repeater on top of a water tower to establish a line-of-sight connection to the PP, which was approximately 1.5 miles away. The second ATOS test site was a 200 x 50 foot storage warehouse (see **Figure 5**). Due to the size of the storage warehouse and the large amount of conventional munitions stored inside this facility, the TM installed 12 RFEs to ensure maximum RF antenna coverage. The TM installed a RCU, PP, and WLAN inside the storage warehouse. The RCU was hardwired to the PP via Ethernet connection. Only 200 RF tags were used in the demonstration based on the approval letters received from the Army and Navy to meet Hazards of Electromagnetic Radiation to Ordnance (HERO) requirements.

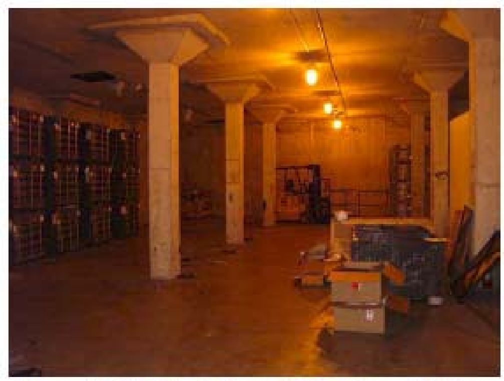


Figure 4. CAAA Earth-Covered Magazine: ATOS was installed in this earth-covered magazine in Crane, IN from 12 to 23 April 2004.

The assessment team collected observation data and administered training questionnaires during the first week of the demonstration. During the second week of the demonstration, the warfighters performed the 19 scenarios listed in Appendix C. The assessment team collected observation data; administered operator, logistics, munitions, and training questionnaires; and collected RCU performance data.

Figure 5. CAAA Storage Warehouse: Twelve RFEs were required to provide complete antenna coverage in a large storage warehouse.

Maritime Demonstration

The purpose of the maritime demonstration was to collect performance data inside ship magazines. The maritime demonstration consisted of two events conducted at Norfolk Naval Station. The first assessment event was conducted on the USS Ponce from 6 to 9 July 2004 to characterize system performance on a combat logistics ship. Since the magazine was very small (10 x 22 x 8 feet), an RCU was not installed (**Figure 6**). In this demonstration, the HHR was used to perform the six munitions management tasks. During this demonstration, it was learned that an RCU was not required to perform munitions management tasks if a HHR and PP were available. The TM staff operated the PP since a warfighter was not available for training during the demonstration. The assessment team observed training and warfighter performance of munitions management tasks. At the end of the first maritime event, the assessment team administered questionnaires.

Figure 6. Close-in Weapons Support Storage on the USS Ponce: A HHR was used to detect 60 RF tags placed inside the storage facility. No RCU was installed inside the magazine.

The second maritime assessment event was conducted 17 to 27 August aboard the USS Harry S. Truman. This assessment was performed in two parts: the first part characterized the ruggedness, reliability, and functionality of 32 RF tags that were attached to munitions pallets and shipped via commercial ground transportation from CAAA to Norfolk, VA; the second part characterized system performance on an aircraft carrier (i.e., a combat ship). The second event installed the ATOS system in a 45 x 80 x 10 foot magazine below the flight deck hangar (**Figure 7**). The assessment team observed training and warfighter performance of munitions management tasks. At the end of the second maritime event, the assessment team administered questionnaires.

Figure 7. Ship Magazine on the USS Harry S. Truman: A member of the TM staff installed wiring for the RFEs.

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RESULTS

Results are presented for environmental surveillance, munitions management tasks, and system characterization. This will facilitate discussion of military utility conclusions and recommendations. As stated earlier, MOEs 1.2 and 1.6 support environmental surveillance, MOEs 2.5 through 2.8 characterize the ATOS system, and the remainder of the MOEs support munitions management. The detailed results by MOE are discussed in Appendix D. Appendix E provides the correlation of FRD requirements to the MOP results. **Appendix F** depicts the correlation of the assessment questionnaires to environmental surveillance, munitons management, and MOPs.

Environmental Surveillance

Data gathered during the TECEVAL indicated that the temperature sensor was accurate to within ± 1° Fahrenheit (F) of the environmental chamber settings, and that the RH was accurate to within ± 10%. These data further indicated that the G-shock sensor was not mature enough to be assessed during the demonstrations because of inadequate electronic coupling between the G-shock sensor and the RF tag board, which caused false shock detections. As a result, the G-shock sensor was not assessed during the demonstrations.

> *"Nice to see the temperature sensor incorporated into the RF tag. It gave an indicator if there was a problem with ammunitions."*
>
> Warfighter comment

For two days during the OCONUS, CONUS, and maritime demonstrations, the assessment team recorded hourly temperature and RH measures using a Kestrel 4000 weather monitoring station. The temperature and RH measurements were compared with the environmental histogram from the RF tag and results indicated that temperature and RH measures correlated with data captured by the assessment team. The RF tags collected and recorded environmental data on the tagged munitions pallets every 60 minutes during all demonstrations.

When the RF tags were created, the environmental sensors began collecting hourly temperature and RH measures. Most of these RF tags had more than 4700 hours of continuous operation from March to August 2004. The assessment team did not observe any failures in the temperature and RH sensors. The TECEVAL data revealed the RF tag can record and store environmental data for 45 days (1080 data points).

During the demonstrations, the TM randomly selected the upper and lower user-selectable temperature and RH limits. Many of these settings were not operationally representative, but did allow assessment of limit flag reporting (i.e., when temperature reached the limit, a flag was set and data were reported to the PP).

The warfighters provided comments about the RF tags' environmental sensors. The warfighters indicated that the temperature sensor capability would provide valuable information. A Miesau warfighter stated, "*The temperature [user-selectable limit] was easy to change*" and will be especially useful when the temperature range requirements for critical munitions are defined in the future.

Although the RF tag performed well during the demonstration, some of the warfighters expressed concerns about the cost of the RF tag, since they were not designed to be reusable. There were also several discussions about the RF tag environmental sensors. One warfighter stated "*The [RF] tags on the outside of container don't accurately give temperature and RH inside the munitions pallets.*" Another warfighter wanted to know immediately when environmental flags were tripped. In addition, one SME commented that it would be useful to know exactly when an environmental flag occurred, and requested that a date/time stamp be added. A CAAA warfighter stated that the RH data would not provide useful information.

Warfighters indicated that having a RF tag that shows when a munitions pallet was dropped is only beneficial if the RF tag can accurately record the distance dropped or shock received. Finally, as stated earlier in the report, the G-shock sensor was not demonstrated during the MUA.

Munitions Management

Pallet Receipt

Pallet receipt consisted of receiving incoming tagged munitions pallets, creating and attaching the RF tag to the munitions pallets, moving the tagged munitions pallets to an initial storage location, and adding the munitions pallets and their content to the inventory. During the demonstrations, the warfighters were able to create new RF tags using the HHR. The warfighters stated "*the creation of a RF tag was easy and straightforward*;" however, the assessment team observed some problems with HHR reading asset data from the RF tags. It may require the warfighter to move the HHR to different angles to read the RF tags. During the demonstrations, HHR took two to five minutes to read and write to a RF tag, and many warfighters complained about the slow processing speed.

During the demonstrations, the warfighters were shown two methods to attach the RF tags to the munitions pallets. The first attachment method used wood screws and the second attachment method used a special double-sided adhesive tape. At the Miesau and CAAA demonstrations, the TM used four RF tags and tag holders to evaluate adhesive attachment to metal and wooden munitions pallets. Tag holders remained attached to both metal and wooden munitions pallets during the demonstrations, but questionnaire results indicated that the RF tags adhered better to metal pallets than to wooden pallets. Warfighters were concerned that the tag holder would fall off the wooden pallets and recommended securing them with wood screws.

During the maritime demonstration, the CAAA logistics personnel attached 32 RF tags to the bottom of the munitions pallets for shipment to Norfolk Naval Station, VA via commercial ground transportation (**Figure 8**). Thirty-two RF tags were placed on the munitions pallets at CAAA, IN and shipped by commercial ground to the Norfolk Naval Station, VA. Because Navy munitions personnel use chains to cradle the pallets from below during loading of the munitions pallets onboard ship, the RF tags were removed from the munitions pallets upon arrival to avoid damage to the RF tags during loading. Thirty-one of 32 RF tags were removed from the munitions pallets and were undamaged and functional. The HHR was used to locate the missing RF tag, which was still attached to a munitions pallet when it was moved to the USS Harry S. Truman's magazine. The RF tag was functional but not visible. The assessment team was not able to verify if the TM staff was able to retrieve the missing RF tag.

Figure 8. RF Tag Placement During Transport to the USS Harry S. Truman: *Thirty-two RF tags were placed on the munitions pallets at CAAA, IN and shipped by commercial ground to the Norfolk Naval Station, VA.*

After RF tags were placed on the munitions pallets, the pallets were moved to a magazine to be interrogated by the RCU. The RCU and RFE were effective in detecting 200 RF tags inside the earth-covered magazines, storage warehouse, and ship magazine. At the OCONUS demonstration, the RCU detected 199 out of 200 RF tags (99.5%) in the earth-covered magazine, and 169 out of 174 RF tags (97.1%) in the ASP. In the CONUS demonstration, the RCU detected 197 out of 200 RF tags in the earth-covered magazine. In both demonstrations, the first interrogation cycle was 14 minutes on the short read and two hours and 30 minutes on the long read. During the second and third interrogation cycles, ATOS was able to detect 100% of the RF tags. At the maritime demonstration, the RCU was able to detect 200 RF tags on the USS Harry S. Truman on the first interrogation cycle. Questionnaire results indicated the RF antenna coverage was acceptable. A WLAN or LAN was used to transfer the interrogated RF tag data (e.g., missing RF tag, environmental flags, and updated environmental history data) from the RCU to the PP.

> *"[RF tag location] is much easier than the current method used now."*
>
> Warfighter comment

When asset information was loaded on the RF tag, the HHR created and stored a transaction record for each RF tag. The transaction record contains the asset information and the latest update in the environmental data. During the CAAA demonstration, the assessment team observed that when the warfighters docked the HHR to the PP, some transaction records did not get transferred to the PP and other transaction records were deleted from the HHR. During the maritime demonstration, a warfighter attempted to transfer 180 transaction records from the HHR to the PP. The HHR software timed out after a few minutes during data transfer to the PP. The TM developed a workaround solution to demonstrate the pallet receipt capability by reducing the number of transaction records (50 records per packet) being transmitted from the HHR. The assessment team also observed an interoperability issue that occurred when two HHRs were within 20 feet of each other, causing the HHRs to lock up. Despite these issues, questionnaire results indicated that the warfighters believed the HHR was user friendly and easy to use during pallet receipt and that the stylus was extremely useful in data entry even when they were wearing bulky work gloves. Questionnaire responses also indicated that warfighters believed the PP was easy to use for pallet receipt.

Inventory Maintenance

During the demonstrations, the RCU maintained the inventory through interrogations of the RF tags every 60 minutes. Once the inventory list reached a steady-state condition, the RCU only reported exceptions to the inventory. If the RCU encountered any environmental alarm flags, low battery power flags, or missing or new RF tags, a warning indicator was graphically displayed on the PP computer screen. These warning indicators remained on the computer screen until the ATOS operator took action to resolve the problem or cleared the warning indicators.

When conducting an inventory using an HHR, warfighters downloaded the inventory list to the HHR from the PP and performed a roll call function (query each RF tag) on the HHR. The HHR compared the downloaded inventory list to the RF tags located inside the magazine. The warfighters were able to quickly inventory 60 RF tags inside the USS Ponce's magazine and identify new or missing tagged munitions pallets using the HHR. The assessment team compared the count of the handwritten inventory list, the HHR transaction records, and the count on the PP inventory. After the inventory was completed, the HHR was docked to the PP for the PP to receive the updated inventory from the HHR.

> *"[ATOS will] reduce the time needed to conduct an inventory of a 60 x 40 x 15 foot earth-covered magazine from six to eight hours to an hour or less."*
>
> Warfighter comment

The assessment team observed that the RCU successfully monitored incoming and outgoing tagged munitions pallets during the Miesau and CAAA demonstrations. The warfighters were able to locate RF tags, verify the inventory list, and identify new and missing RF tags inside the magazine. Assessment team observations indicated that the PP had sufficient bandwidth, connectivity, and data storage to perform the inventory maintenance task. Questionnaire results indicated that the warfighters believed that the RF tags, HHR, and PP were easy to configure for inventory maintenance.

During the maritime demonstration, the PP locked up when downloading the inventory of 200 RF tags to the HHR. The TM identified this as a PP software problem. In addition, the assessment team observed that because RCU operation could not be paused during its interrogation cycle, the warfighters were unable to conduct an inventory until the interrogation cycle was finished.

Pallet Movement

During pallet movement, warfighters used the HHR to update the location field on the RF tag, and the RCU updated the location field on the PP inventory list. During the pallet movement demonstration, no RF tags were physically attached to the munitions pallets stored inside the magazine. The assessment team selected five RF tags and had them removed from an earth-covered magazine at Miesau and CAAA demonstrations. Two RF tags were moved to a storage warehouse that had a different RCU. The other three RF tags were placed inside a munitions container and moved away from the magazine to simulate munitions pallets in transit. The RCU detected the two RF tags inside the storage warehouse as existing inventory and updated the RF tag location field, and the warfighter used the HHR to update the RF tag information. The PP identified the three missing RF tags by ID number. When the three RF tags were placed back inside the magazine, the missing RF tag notifications were removed from the PP display during the next RCU interrogation cycle. During the maritime demonstration, the assessment team removed 20 RF tags from the ship's magazine to simulate a pallet movement. The PP again identified the missing RF tags by ID number. When 10 RF tags were placed back into the magazine, the PP identified only the ten remaining missing RF tags. As long as the tagged munitions pallets remained with the assigned RCU ID, they could be moved anywhere within the magazine without the PP indicating missing RF tags. If the tagged munitions pallets were removed from the assigned RCU area of coverage, the PP notified the warfighters within 60 minutes of the last RCU interrogation cycle that the pallets had been moved. If the tagged munitions pallets were moved to a different building with a different RCU ID, the RCU would update the RF tag with a new RCU ID number. The assessment team verified the location changes in the HHR and PP. If the tagged munitions pallet was moved before the start of the next interrogation cycle, the PP does not receive a flag warning. The assessment team observed that the PP, HHR, and RCU had sufficient bandwidth, connectivity, and data storage to perform pallet movement. Questionnaire results indicated that the warfighters believed the HHR and PP were easy to configure and use for pallet movement.

Pallet Issue

During pallet issue, the warfighters simulated the issue of one or more individual munitions items from tagged munitions pallets, using the HHR to update the munitions count on the RF tag. The HHR was later docked with the PP and the inventory was updated to reflect the new munitions count. The RCU interrogated the RF tags every 60 minutes to collect any changes in the asset data. Questionnaire responses indicated the warfighters thought the HHR was easy to configure and use to update the munitions count. The assessment team observed that the HHR had sufficient data storage for pallet issue.

Pallet Transfer

During pallet transfer, warfighters prepared the tagged munitions pallets for shipment outside the depot, using the HHR to download the latest asset and environment data and any environmental flags. The warfighters docked the HHR to transfer the data to the PP. The RF tag ID number was removed from the inventory and the data archived. The assessment team observed the warfighters download the asset and environmental data using the HHR. The assessment team also observed warfighters using the HHR keypad and stylus to update the asset data and transfer the information to the PP. The PP, HHR, and RCU had sufficient data storage for pallet transfer. Questionnaire results indicated that warfighters believed the HHR to be instrumental in transferring tagged munitions pallets.

Munitions QA

The Munitions QA task was not assessed during the demonstrations (see limitations and constraints section). From a Quality Assurance Specialist Ammunition Surveillance specialist viewpoint, the current design does not have any applicability for quality control. Questionnaire responses indicated the RF tag does not have any fields that contain information about the inspection history, recent suspense information, or condition code changes that could impact serviceability of the munitions items.

System Characterization

Training

The warfighters indicated the training was effective in providing the necessary information to operate the ATOS system during the demonstrations. The training material was easy to understand and the system was easy to operate. All of the warfighters wanted more hands-on time with the system during the classroom instruction. They also would like to have had a training/user manual available during the classroom instruction.

> *"For myself, the hands-on training was how I really began to understand how the units work."*
>
> Warfighter comment

Component Ruggedness

The assessment of the ATOS component ruggedness was limited. The TECEVAL data revealed that the RF tags meet the ruggedness requirements stipulated in the FRD. The assessment team collected a limited amount of handling data during shipment from the CAAA to Norfolk Naval Station. All RF tags performed nominally during the demonstrations. The assessment team observed two inoperable RF tags (one RF tag from the Miesau demonstration and one RF tag in the maritime demonstration). The TM is currently investigating the causes of the failures. The assessment team did not observe any HHR or PP failures. The assessment team observed two RCU failures. The first failure occurred at the Miesau demonstration and was caused by a faulty flash memory card. The second failure occurred at the maritime demonstration and was caused by a faulty power supply.

Power Requirement

No RF tags were replaced during the demonstrations due to low battery power. Questionnaire results indicated that the warfighters would prefer to be able to replace RF tag batteries rather than throwing away the entire RF tag. The HHR used two rechargeable batteries and docking stations to ensure power was maintained. The RCU was able to operate as long as 24 VDC power was available. During all demonstrations, a portable gas electric generator, High Mobility Multipurpose Wheeled Vehicle battery, or 120/220 volts alternating current (VAC) line power and 24 VDC step down were used to provide electrical power. The warfighters stated that the PP power requirements were straightforward and easy to accommodate as long as the PP was hosted in a facility that had 120/220 VAC electrical power.

Installation

During the ATOS ACTD, the TMs staff installed the RCU, RFEs, WLAN or LAN inside the magazines, storage warehouse, ASP, and ship magazines. The number of RFEs required to detect 200 RF tags was determined by the size and configuration of the magazine. Typically, the installation took approximately two days to accomplish at each demonstration site. On the third day, the TMs staff would lay out 200 RF tags and conduct several experiments to determine the optimum position for the RFEs to detect 100% of RF tags inside the magazine.

Questionnaire results indicated the warfighters believed the location and accessibility of the RCU were acceptable for the demonstrations. Tie wraps were used to install the RFEs, while the RCUs were mounted on portable stands. The PP installation was straightforward since the software was pre-installed on a laptop computer.

Security

The network security of the ATOS system was not assessed due to the unavailability of information security SMEs.

Conclusions and Recommendations

The ATOS system demonstrated potential military utility and was effective in providing environmental surveillance and enhancing munitions management. Although there were some technical problems encountered during the demonstrations, the system was able to provide the warfighters near real-time environmental data and support five out of the six munitions management tasks during the demonstrations. **Table 7** identifies the environmental surveillance and munitions management ratings based on the assessment team's findings.

Table 7. MUA Utility Ratings: *The system was effective in providing the warfighter with environmental surveillance data and enhancing munitions management.*

ATOS System Capability	Rating
Environmental Surveillance	△
Munitions Management	
Pallet Receipt	▽
Inventory Maintenance	▽
Pallet Movement	△
Pallet Issue	▲
Pallet Transfer	▲
Munitions Quality Assurance	⬭
System Characterization	
Training	▲
Ruggedness	⬭
Power	▲
Installation	▲
Security	⬭

Legend

- ▲ Demonstrated utility; deployable now; minor improvements recommended.
- △ Potential utility; minor improvements recommended.
- ▽ Potential utility; major improvements required.
- ▼ No utility demonstrated; possible utility; complete redesign needed.
- ⬭ Insufficient data or not assessed.

Environmental Surveillance

The RF tag demonstrated military utility and was effective in providing the warfighters a new capability for collecting environmental data on tagged munitions pallets. RF tag histogram data correlated closely with the measurements taken by the assessment team during the demonstrations. The warfighters would like to have the sensors embedded in the munitions so that accurate environmental readings can be obtained for individual items and for conditions inside the pallet.

Munitions Management

The consensus of the warfighters was that the ATOS system demonstrated military utility and enhanced the logistics process for managing munitions pallets. The warfighters were impressed with the automated capability to track and monitor incoming and outgoing tagged munitions pallets during pallet movement, pallet issue, and pallet transfer. Listed below are the conclusions for each munitions management task.

Pallet Receipt

The ATOS system demonstrated potential military utility, but will require major improvement. The system was effective in performing pallet receipt of 20 to 60 RF tags and reduced the time to receipt incoming munitions pallets. However, the technical problems encountered during demonstrations make the system performance unacceptable. Reading and writing data to and from the RF tag using the HHR was time consuming, there were data transfer problems between the HHR and PP, and an interoperability problem occurred when two HHRs were within 20 feet of one another. This system performance was unacceptable to the warfighter since a depot routinely receives large numbers of incoming munitions pallets.

Inventory Maintenance

The ATOS system demonstrated potential military utility, but will require major improvement. The system was effective in performing the inventory task and reduced the time needed to conduct an inventory. "*The HHR and RCU were useful in tracking incoming and outgoing tagged munitions pallets and identifying alarms*." However, the PP was unable to download the entire inventory of 200 RF tags without locking up. This function must be fixed before the system is deployed to the warfighter.

Pallet Movement

The ATOS system demonstrated potential military utility, but will require minor improvement. The system was effective in performing pallet movement, with the warfighters being able to use the HHR to update the location field on the RF tag. However, the system does not alert the PP with a flag indicator when a RF tag has been moved to a different building and interrogated by a different RCU. A warning indicator should be incorporated in the PP software which will identify any tagged munition pallets that were moved before the next interrogation cycle. Otherwise, the PP was able to verify that tagged munitions pallets had been moved from one location to another within the same depot.

Pallet Issue

The ATOS system demonstrated military utility and was effective in performing pallet issue, with warfighters being able to use the HHR to update the munitions count on the RF tag and the RCU successfully capturing the munitions count changes and reconciling them with the inventory on the PP.

Pallet Transfer

The ATOS system demonstrated military utility and was effective in performing the pallet transfer. The warfighters were able to download asset and environmental data from the RF tags using the HHR and transfer the data to the PP where the RF tag ID was removed from the inventory and the data archived.

Munitions QA

The Munitions QA task was not assessed by the assessment team during the demonstrations.

System Characterization

Training

The overall feedback the assessment team received from the warfighter was that the ATOS system training was adequate and provided the necessary information to operate the system. The warfighter indicated the training was effective in providing the necessary information to operate the ATOS system during the demonstrations.

Component Ruggedness

The ATOS system components performed nominally during the demonstration. The assessment team did not observe any major failures that the TM could not recover in a couple of hours. ATOS performed most of the munitions tasks with no major issues.

Power Requirement

No major issues were identified at the demonstration sites in providing the necessary power to support ATOS. The warfighters wanted a capability to replace the batteries in the RF tag.

Installation

ATOS component installation was straightforward and easy. No major issues were identified at the demonstrations.

Security

Security was not assessed by the assessment team during the demonstrations.

Recommendations

Recommendations are based on warfighter inputs and the results from the ATOS MUA. These recommendations were separated into two categories: 11 recommendations for system improvements and two recommendations for further testing.

Environmental Surveillance

- Provide time and date stamp association to determine when a critical munitions item experienced extreme temperature and RH variations.
- Develop reusable RF tags
- Develop and demonstrate a G-shock sensor capability
- Attach RF tags to inside of individual munitions containers
- Develop environmental sensors that are embedded in the munitions

Munitions Management

- Reduce HHR read and write processing speed from 5 minutes to 40 seconds or less
- Fix the data transfer problem with the HHR so that it is able to transfer the designed number of transaction records (approximately 1,000) to the PP
- Develop procedures or software modifications allowing the use of HHRs in close proximity of each other
- Develop a pause function on the RCU to allow the warfighters to perform logistical tasks using the HHR
- Fix the PP data transfer problem so that the HHR can download the entire inventory list to the HHR
- Modify the RF tag so that munitions QA can document condition codes and inspection history

Test Refinement

- Evaluate the interoperability of the Service Ammunition AIS and EDB with ATOS
- Evaluate network security of the ATOS system

APPENDIX

ACRONYM LIST

A

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ACTD	advanced concept technology demonstration
AFOTEC	Air Force Operational Test and Evaluation Center
AIS	automated information system
AIT	automatic identification technologies
AOR	area of responsibility
ASP	ammunition supply point
ATOS	Advanced Technology Ordnance Surveillance
CAAA	Crane Army Ammunition Activity
COI	critical operational issues
CONOPS	concept of operations
CONUS	continental United States
COTS	commercial off-the-shelf
Det 1	Detachment 1
DoD	Department of Defense
DODIC	DoD Identification Code
EDB	environmental database
F	fahrenheit
FRD	functional requirement document
G-shock	gravity-shock
HERO	Hazards of Electromagnetic Radiation to Ordnance
HHR	handheld reader
ID	identification
JMC	Joint Munitions Command
LAN	local area network
LCD	liquid crystal display
MB	megabytes
MEMS	micro-electromechanical systems
MHz	MegaHertz
MOE	measures of effectiveness
MOP	measure of performance
MUA	military utility assessment
mW	milliwatt
NAVSEA	Naval Sea Systems Command
NSN	National Stock Number
NSWC	Naval Surface Warfare Center
OCONUS	outside the continental United States
OM	Operational Manager
PP	preprocessor
QA	Quality Assurance

RCU	reader control unit
RF	radio frequency
RFE	radio frequency extenders
RH	relative humidity
SME	subject matter expert
TECEVAL	technical evaluation
TM	technical manager
USEUCOM	US European Command
USS	United States Ship
VAC	volts alternating current
VDC	volts direct current
WLAN	wireless local area network

Appendix B

Correlation of Environmental Surveillance and Munitions Management to Measures of Effectiveness

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Table B-1 correlates MOEs addressed during the MUA with environmental surveillance and munitions management tasks.

Table B-1. Correlation of MOEs to Environmental Surveillance and Munitions Management Tasks: The MOEs were correlated to the environmental surveillance and munitions management tasks to illustrate the assessment methodology.

Correlation of Munitions Management and Environmental Surveillance to MOEs							
		Munitions Management					
MOE	Environmental Surveillance	Pallet Receipt	Inventory Maintenance	Pallet Movement	Pallet Issue	Pallet Transfer	Munitions QA
COI 1. Does ATOS support asset visibility, accountability, and serviceability for munitions?							
1.1 Capability of ATOS system to provide container location data		•	•	•	•		•
1.2 Capability of ATOS system to accurately report and maintain environmental data on containers	•						
1.3 Capability of ATOS RF tags to communicate with RCU or HHR		•	•	•	•	•	•
1.4 Capability of ATOS HHR and RCU to communicate and transfer data to PP		•	•	•	•	•	•
1.5 Capability of ATOS PP to interoperate with Service Ammunition AIS	Not Assessed						
1.6 Capability of ATOS PP to interoperate with EDB	Not Assessed						
1.7 Characterization of network bandwidth connectivity to ATOS PP		•	•	•	•	•	•
1.8 Capability of ATOS system to protect data		•	•	•	•	•	•
1.9 Capability of ATOS system to provide sufficient data storage		•	•	•	•	•	•
1.10 Characterization of ATOS RCU antenna coverage		•	•	•	•		•
1.11 Capability of ATOS RCU to detect RF tags at initial startup		•					•
1.12 Usability of ATOS HHR input devices		•	•	•	•	•	•
1.13 Capability of ATOS HHR to create RF tags and barcodes		•					
COI 2. Is ATOS supportable for military operations?							
2.1 Reliability of ATOS RF tag attachment		•	•	•	•	•	•
2.2 Usability of ATOS HHR and RCU		•	•	•	•	•	•
2.3 Usability of ATOS PP		•	•	•	•	•	•
2.4 Ease of configuration for ATOS components		•	•	•	•	•	•
2.5 Adequacy of ATOS training		•	•	•	•	•	•
2.6 Adequacy of ATOS component ruggedness		•	•	•	•	•	•
2.7 Supportability of ATOS power requirements		•	•	•	•	•	•
2.8 Supportability of ATOS installation		•	•	•	•	•	•

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APPENDIX C

DETAILED SCENARIOS

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Table C-1 describes the 19 scenarios that were used to demonstrate environmental surveillance and munitions management capabilities. Each scenario was repeated at least five times by the participants to ensure they completely understood the ATOS system operations.

Table C-1. MUA Scenario: Nineteen scenarios were conducted to ensure all ATOS functions were assessed.

ATOS Scenario	
Scenario Script	**Description**
1. Demonstrate capability to conduct the administrator functions of the PP and HHR.	Operators perform administrative and set-up functions with HHR prior to start of the demonstration, which includes docking the HHR to the PP and configuring the PP and the RCU.
2. Demonstrate PP operations in conjunction with the HHR and RCU operations.	Operators conduct munitions management tasks using the HHR, RCU, and PP.
3. Demonstrate how to set the sensor alarm thresholds.	Operators set RF tag sensor alarm thresholds during initial creation of RF tags; thresholds for some RF tags are set above or below ambient temperatures to trigger alarms.
4. Create new RF tags with the HHR (using keypad).	Operators create 25 RF tags using the HHR keypad to enter asset information.
5. Create new RF tags using data from the PP.	Operators create five RF tags using asset information from the PP (downloaded from the PP to the HHR and transferred to RF tag).
6. Create new RF tags using data from bar code labels.	Operators create five RF tags using data from bar code labels.
7. Perform inner-area of movement tagged munitions pallets.	Operators move RF tags from one location to another within the munitions facility.
8. Move tagged munitions pallet with a bad RF tag (not responding due to dead battery).	Operators move bad RF tags from one location to another within the munitions facility and replace bad RF tags with fully functional items.
9. Move tagged munitions pallet with a bad RF tag (reason other than dead battery).	Operators move bad RF tags from one location to another within the munitions facility, simulate dead RF tag, and simulated bad RF tag with fully functional item.
10. Movement of asset with a tripped sensor alarm.	Operators perform inventory actions to address tripped sensor alarms.
11. Movement of tagged munitions pallet with low battery.	Operators move an RF tag with low battery from one location to another within the munitions facility and replace the RF tag with one that has a fully functional battery.
12. Change RF tag data.	Operators edit asset information on RF tags using the HHR, read the edited information using the RCU, and update the PP using the HHR via docking station.
13. Asset receipt.	Operators perform asset transactions, such as pallet receipt.
14. Asset issue (entire pallet with RF tag).	Operators use the HHR to issue contents of an entire tagged munitions pallet.
15. Asset issue (partial pallet - RF tag remains).	Operators use the HHR to issue some of the contents from a tagged munitions pallet, noting the quantity and type of items issued.
16. Asset transfer (shipment).	Operators transfer tagged munitions pallet from one location to another and validate transaction (i.e., determine if asset data elements in the PP match those that were transferred).
17. Perform inventory of all tagged munitions pallets in a storage location.	Operators use the HHR roll call function to conduct munitions inventory.
18. Search for and identify various RF tag using HHR find function.	Operators use the HHR roll call function to find tagged munitions pallets.
19. Download RCU files.	Operators use the HHR to download interrogation files from the RCU.

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Appendix D

Measures of Performance Results

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This appendix presents the detailed results for the MOEs and MOPs used to derive the results and conclusions for the ATOS MUA. The bar charts show aggregated responses from operators, logistics, and munitions participants. The analysis revealed no significant differences in warfighters' opinions at the demonstrations.

MOE 1.1 Capability of ATOS system to provide container location data

This MOE assesses the ATOS capability to provide and update location data (building grid coordinate) on tagged munitions pallets. During the demonstrations, the RF tag was able to maintain location field data and gave the warfighter a capability to update RF tag location information.

MOP 1.1.1 Capability of ATOS system to provide container location data

The HHR was used by the warfighters to input building coordination grids into the RF tag location data field and the RCU then updated the RCU location field on the PP. At each demonstration site, the warfighters were tasked to change the location field on 20 RF tags. The assessment team verified the location changes in the HHR and PP. As long as the tagged munitions pallets remained within the assigned RCU ID, the tagged munitions pallets could be moved anywhere in the magazine and the PP would not flag a missing RF tag. If the tagged munitions pallets were moved to a different building with a different RCU ID before the 60-minute interrogation cycle, the new RCU would update the RF tag with a new RCU ID number. The warfighter would not be notified when tagged munitions pallets were moved to a different location since the PP would reconcile the inventory and show the tagged munitions pallets were picked up by another RCU. Therefore, the warfighter would not know the location of a moved tagged munition pallet without referring to the PP. One warfighter stated the RF tag location capability is *"Much easier than the current method used now."*

MOP 1.1.2 Operator assessment of RF tag location capability

The questionnaire responses indicated the RF tag location capability was acceptable in supporting the warfighter in locating tagged munitions pallets (**Figure D-1**). The warfighters believed the RF tag location capability made their job of locating tagged munitions pallets easier. A CAAA warfighter stated, *"The accuracy of the location reports would be useful. However, need to see ATOS work in a jam stow [munitions pallets stacked end-to-end] environment."*

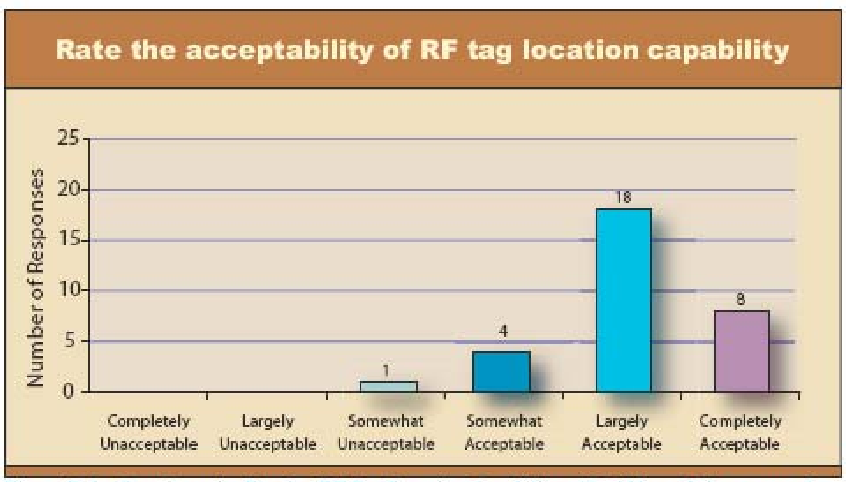

Figure D-1. Questionnaire Results, RF Tag Location Capability: 30 of 31 warfighters agreed that the RF tag location capability was acceptable.

MOE 1.2 Capability of ATOS system to accurately report and maintain environmental data on containers

This MOE assesses RF tag capability to accurately measure temperature, RH, and G-shock; and to alert the operator if an environmental condition exceeds the threshold of the munitions. Although the RF tags collected environmental data, the assessment team received a few negative comments. One CAAA warfighter felt the RH data would not provide useful information. Another warfighter stated, "*Tags on the outside of container does not [sic] accurately give temperature and RH inside the munitions pallets.*"

MOP 1.2.1 Percentage of ATOS RF tags that accurately report and maintain environmental data of the containers

During TECEVAL, 20 RF tags were placed inside an environmental chamber to determine if the RF tags accurately recorded the temperature and RH. The histogram data revealed all 20 RF tags (100%) accurately recorded the temperature and RH data. During the demonstrations, the RF tag histogram data correlated with the temperature and RH data collected by the assessment team.

MOP 1.2.2 RF tag temperature accuracy

The TECEVAL data indicated the temperature sensors on the 20 RF tags were accurate within ± 1°F readings from the environmental chamber settings. The assessment team was unable to measure temperature accuracy during the demonstrations because the method on how the RF tag collects temperature data was changed to develop the histogram data. Therefore, the data was unavailable to the assessment team.

MOP 1.2.3 Reliability of RF tag temperature sensor

When the RF tags were initialized, they continued to collect hourly temperature measures. Most of the histogram information RF tags had more than 4,700 hours of continuous operation. The assessment team did not observe any failures in the temperature sensor.

MOP 1.2.4 RF tag relative humidity accuracy

The TECEVAL data indicated the RH was accurate within ± 10% of the environmental chamber settings. TECEVAL data also indicated that the RH sensor would give erroneous readings if the RH was above 95% or below 10%. The assessment team was unable to measure RH accuracy during the demonstration because the method on how the RF tag collect RH data was changed to develop histogram data.

MOP 1.2.5 Reliability of RF tag relative humidity sensor

When the RF tags were initialized, they continued to collect hourly RH measures. Most of the RF tags were initialized in March 2004 (more than 4,700 hours). The assessment team did not observe any failures in the RH sensor.

MOP 1.2.6 RF Tag gravity-shock accuracy

Not assessed. The G-shock sensor was not available to support the demonstrations.

MOP 1.2.7 Reliability of RF tag gravity-shock sensor

Not assessed. The G-shock sensor was not available to support the demonstrations.

MOP 1.2.8 Number of days RF tag accurately records and stores environmental data

Not assessed. The TECEVAL data revealed the RF tag could record and store 45 days (1080 data points) of environmental data. Since RF tags were cleared for each demonstration, the assessment team was not able to assess maximum number of days the RF tag could accurately record and store environmental data. The assessment team observed no problems with the RF tags holding all the environmental data during the demonstration.

MOP 1.2.9 Frequency of temperature reports stored in RF tag

The RF tag was designed to collect temperature reports every 60 minutes when initialized. The results indicated the RF tag collected and recorded temperature data every 60 minutes.

MOP 1.2.10 Frequency of relative humidity reports stored in RF tag

The RF tag was designed to collect RH reports every 60 minutes when initialized. The results indicated the RF tag collected and recorded RH data every 60 minutes.

MOP 1.2.11 Number of temperature reports above a user-selectable limit

TECEVAL data showed 20 RF tags had their upper temperature limits set. All 20 RF tags had their environment flags tripped at the appropriate temperature settings.

MOP 1.2.12 Number of temperature reports below a user-selectable limit

TECEVAL data showed 20 RF tags had their lower temperature limits set. All 20 RF tags had their environment flags tripped at the appropriate temperature settings.

MOP 1.2.13 Number of relative humidity reports above a user-selectable limit

TECEVAL data showed 20 RF tags had their upper RH limits set. All 20 RF tags had their environment flags tripped at the appropriate RH settings.

MOP 1.2.14 Number of relative humidity reports below a user-selectable limit

TECEVAL data showed 20 RF tags had their lower RH limits set. All 20 RF tags had their environment flags tripped at the appropriate RH settings.

MOP 1.2.15 Number of gravity-shock sensor reports above the first limit on the x-axis

Not assessed

MOP 1.2.16 Number of gravity-shock sensor reports above the second limit on the x-axis

Not assessed

MOP 1.2.17 Number of gravity-shock sensor reports above the first limit on the y-axis

Not assessed

MOP 1.2.18 Number of gravity-shock sensor reports above the second limit on the y-axis

Not assessed

MOP 1.2.19 Number of gravity-shock sensor reports above the first limit on the z-axis

Not assessed

MOP 1.2.20 Number of gravity-shock sensor reports above the second limit on the z-axis

Not assessed

MOP 1.2.21 SME assessment of RF tag temperature sensor

SMEs and operators indicated that the RF tag temperature sensor was acceptable for measuring tagged munitions pallets ambient temperature (**Figure D-2**). One munitions SME provided this comment, "*Although the temperature sensor and its application are acceptable, the ammunition surveillance community has not caught up to this level of applicability.*" One ATOS operator stated that it was "*Nice to see that this capability was incorporated into the tag. It gave the warfighter an indicator if there was a problem with ammunitons.*" SMEs also indicated that although the RF tags on the outside of the container do not provide temperature readings for the inside of the container, the capability was better than not having any temperature measurements.

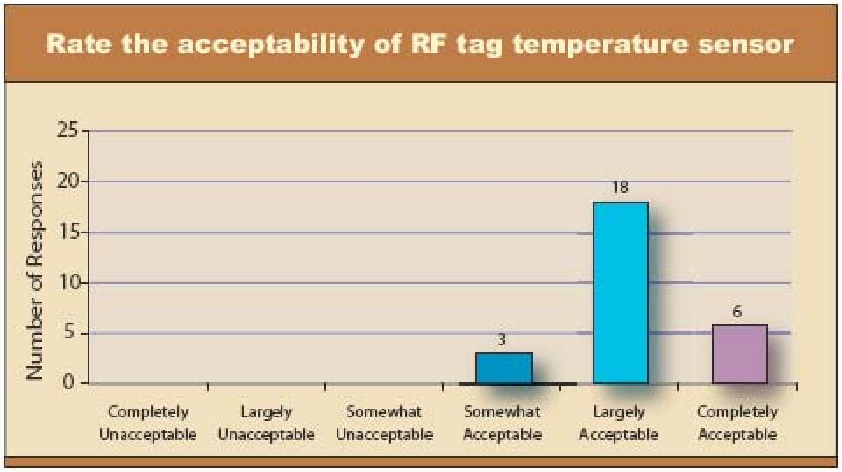

Figure D-2. Questionnaire Results, RF Tag Temperature Sensor: *All respondents agreed that the temperature sensors were acceptable.*

MOP 1.2.22 SME assessment of RF tag relative humidity sensor

SMEs indicated the RH sensor concept was good (**Figure D-3**); however, the current application of the RH sensor needs to be changed to be usable to the naval warfighters. The placement of the RH sensor should reflect what is going on inside of the sealed container, not on the outside of the container. One warfighter indicated *"The need to get relative humidity sensor inside the container."* The questionnaire responses indicated that the RH sensor was acceptable for providing RH measures on tagged munitions pallets.

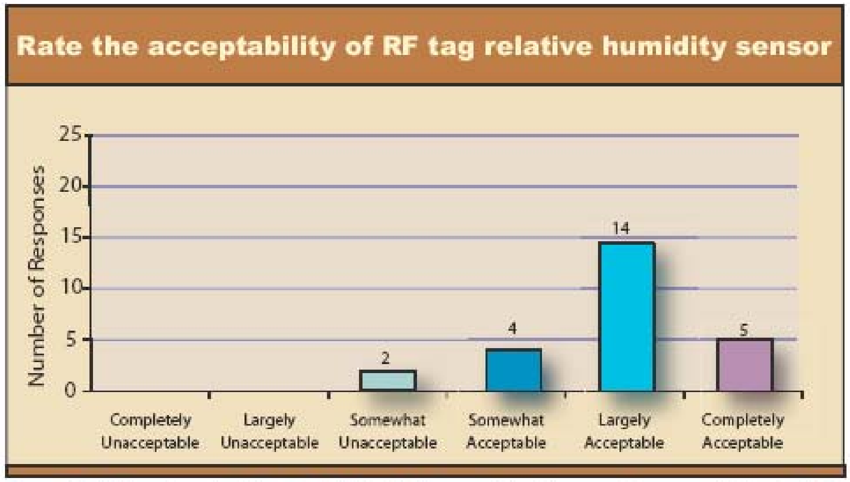

***Figure D-3. Questionnaire Results, RF Tag RH Sensor:** 23 of 25 respondents agreed that the RH sensor was acceptable.*

MOP 1.2.23 SME assessment of RF tag environmental sensor reliability

The SME indicated the RF tag environmental sensor was reliable based on the limited amount of time the warfighters used the RF tags (**Figure D-4**). However, all warfighters indicated the RF tags performed well during the demonstrations.

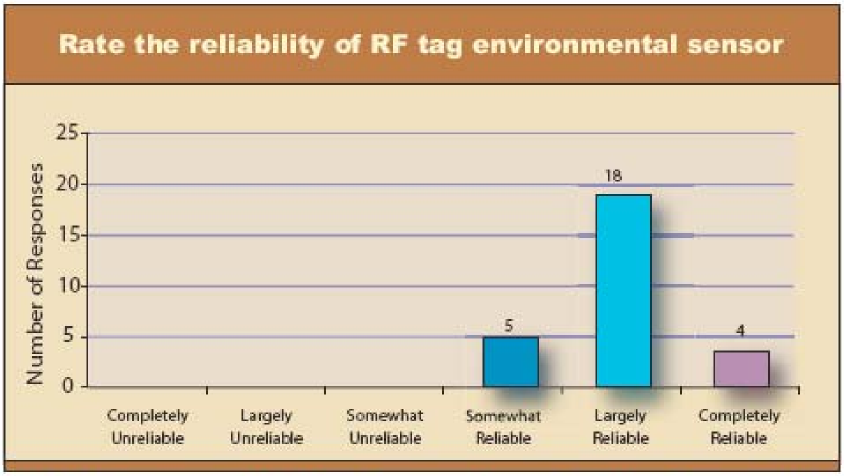

***Figure D-4. Questionnaire Results, Tag Environmental Sensor:** 100% of warfighters agreed that the RF tag environmental sensor was reliable during the demonstration.*

MOP 1.2.24 SME assessment of RF tag gravity-shock sensor

Not assessed

MOE 1.3 Capability of ATOS RF tags to communicate with RCU or HHR

This MOE assesses the RCU capability to interrogate the RF tags and the HHR capability to query RF tags for asset and environmental data. The questionnaire results indicated the data transfer speed for reading RF tag data using the HHR was too slow while conducting pallet receipt. During pallet issue, the RF tags were able to communicate the pallet content changes to the RCU and HHR. During pallet transfer, RF tags were able to communicate the latest asset and environmental data to the RCU and HHR.

MOP 1.3.1 Number of ATOS RF tags that were able to communicate with RCU or HHR

Miesau demonstration: During the first interrogation cycle, the RCU detected 199 out of 200 RF tags (99.5%) in a 60 x 40 x 15 foot earth-covered magazine using three RFEs. The RCU detected 169 out of 174 tags (97.1%) in a 70 x 200 foot ASP using eight RFEs. During the second interrogation cycle, 100% of the RF tags were detected.

CAAA demonstration: The RCU detected 197 out of 200 tags (98.5%) in both the 100 x 50 x 10 foot earth-covered magazine using 6 RFEs and the 200 x 50 foot storage warehouse using 12 RFEs. During the second interrogation cycle, 100% of the RF tags were detected.

Maritime demonstration: The HHR detected 60 out of 60 RF tags (100%) in a 10 x 22 x 8 foot magazine on the USS Ponce. On the USS Harry S. Truman, the RCU detected 200 out of 200 RF tags (100%) in a 45 x 80 x 10 foot magazine using 3 RFEs.

MOP 1.3.2 Automatic reporting frequency from RF tag to RCU

A RCU performance log was used at the Miesau and CAAA demonstrations to monitor the start and stop times of the RCU interrogation cycles. The results indicated that the RCU interrogated the RF tags every 60 minutes.

MOP 1.3.3 On-command reporting to HHR

On-command reporting is the HHR capability to perform roll call or find functions. At the Miseau demonstration, the warfighters used the HHR find function to locate five tagged munitions pallets. All five tagged pallets were located using the HHR. No major problems were observed during the demonstrations. At the CAAA demonstration, warfighters were able to conduct an inventory of 20 RF tags in an earth-covered magazine within 20 minutes. The warfighters indicated this function was a time saver. During the maritime demonstration, the HHR was effective in performing a rapid tally (within 10 minutes) of 60 RF tags inside the USS Ponce's 10 x 22 x 8 storage facility. On the USS Harry S. Truman, Det 1 AFOTEC performed a roll call of 200 RF tags within 15 minutes. *"The warfighters indicated the system seemed slow, but I feel it will execute better when the bugs are worked out."* **Figure D-5** shows responses to the on-command reporting to the HHR questionnaire statement.

Figure D-5. Questionnaire Results, On-Command Report: *All responses agreed that the HHR on-command reporting was acceptable.*

MOP 1.3.4 On-command memory reset from HHR

During the creation of a new RF tag, the RF tag was given a command by the HHR to clear its memory. The assessment team observed that 18 warfighters successfully cleared the RF tag's memory before inputting asset data into the RF tag. This process was a one-time action that was conducted by the TM staff and ATOS participants during pallet receipt. The warfighter stated that "*The tag must be reusable, we must have options to rewrite the tag for different items.*" **Figure D-6** shows the response to the questionnaire statement about the on-command memory reset.

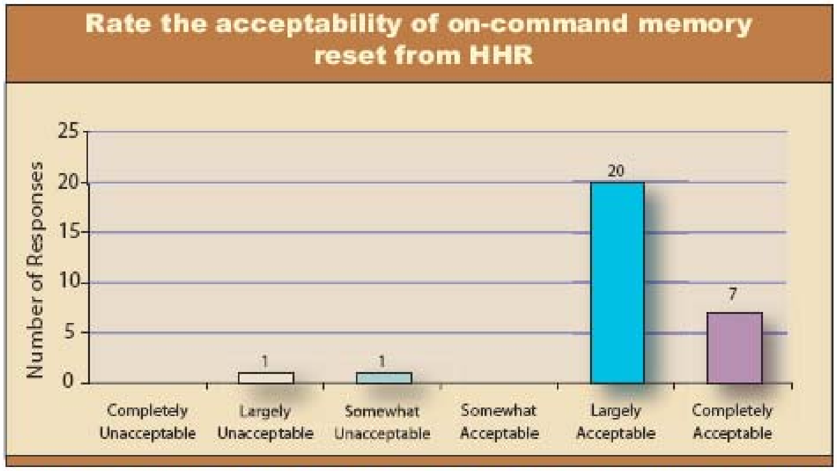

Figure D-6. Questionnaire Results, On-Command Memory Reset: *27 of 29 respondents agreed the on-command memory reset was acceptable.*

MOP 1.3.5 Percentage of RF tags properly identified by their assigned ID number

During the Miesau and CAAA demonstrations, the warfighters assigned ID numbers to 20 RF tags. The warfighters were able to identify all 20 RF tags using the HHR. During the maritime demonstration, the warfighters assigned ID numbers to 60 RF tags. The warfighters were able to properly identify all 60 RF tags by their assigned tag ID numbers.

MOP 1.3.6 RF tag identifier humanly visible

The assessment team observed that the warfighters were able to visually identify 20 selected RF tags by their ID numbers at each demonstration. No distance requirements was stipulated in the FRD. One warfighter stated that the "*ID numbers were readable and easily located.*" **Figure D-7** shows responses to the questionnaires statement about identifying RF tags unique ID number.

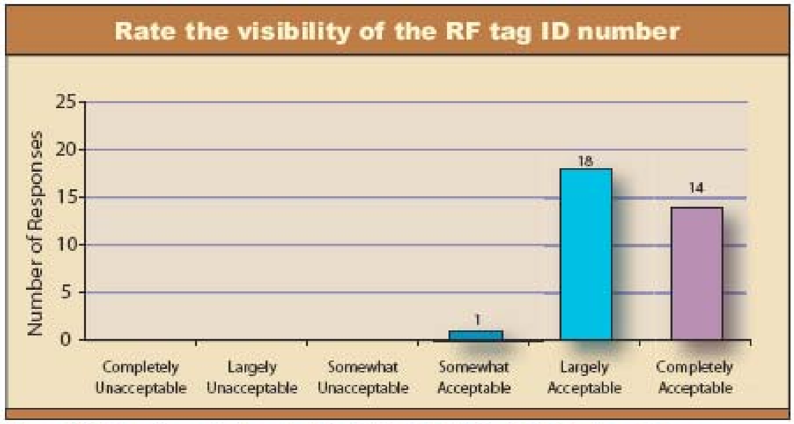

Figure D-7. Questionnaire Results, Identifying the RF Tags' ID Number: All responses agreed that the unique ID number was identifiable on the RF tags.

MOP 1.3.7 RF tag barcode readable

The HHR was able to read the 200 RF tag barcodes at each demonstration site, but based on assessment team observations, the HHR had some problems reading the RF tag barcode if the warfighter didn't place the HHR close enough to the RF tag to read the barcode. Several warfighters stated, "*[The] HHR had some difficulty reading tags consistently.*" **Figure D-8** shows responses to the questionnaire statement about the readability of the RF tag barcode.

Figure D-8. Questionnaire Results, RF Tag Barcode Readability: All responses agreed that the RF tag barcode readability was acceptable.

MOP 1.3.8 RF tag low battery power indication [backup battery]

The TECEVAL data revealed that 20 RF tags switched over to their backup batteries and sent battery flags to the PP when their main cells fell below 3.2 volts. During the maritime demonstrations, the assessment team observed one RF tag transmitted a battery flag. Some of the warfighters indicated, *"The RF tag needed a small light emitting diode or a test port to check the amount of electrical power left in the battery."*

MOP 1.3.9 Operator assessment of the RF tag low battery power indicator

The assessment team received positive comments about the RF tag low battery power indicator (**Figure D-9**). Some warfighters felt it would be beneficial to have a visual indicator on the RF tag itself that displays when the battery has switched over to the backup [battery] rather than having to check the PP for a flag indication. This would allow more time to change out the battery and not risk losing vital information. Other warfighters recommended that the RF tags should have a visual indicator on the outside of the RF tag casing. The questionnaire responses indicated the RF tag low battery power indicator was acceptable for monitoring the battery power level on the RF tag.

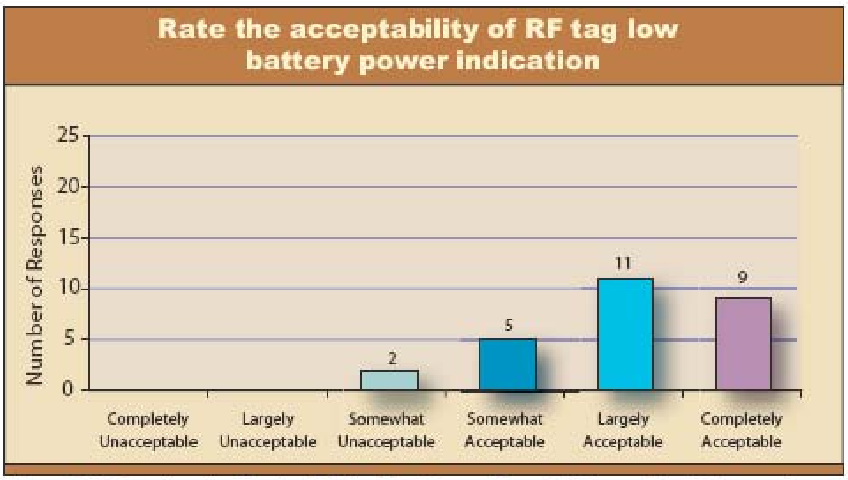

Figure D-9. Questionnaire Results, RF Tag Low Battery Power Indicator: *25 of 27 respondents agreed that the RF tag low battery power indicator was acceptable.*

MOP 1.3.10 Detection range between RF tags and HHR

The maximum detection range between RF tags and the HHR was approximately 80 feet based on assessment team observations.

MOP 1.3.11 Detection range between RF tags and RCU

The TECEVAL data indicated the maximum detection range for the RCU was approximately 100 feet.

MOP 1.3.12 RF tag transmitter radiation parameters

The RF tag transmitter power was at 240 milliwatts (mW), which met HERO requirements.

MOP 1.3.13 RF tag transmitter frequencies

The RF tag transmitter frequency was 433.92 Megahertz (MHz), which met HERO requirements.

MOP 1.3.14 Anti-collision communications between RF tag, HHR, and RCU

This MOP assesses any communication conflicts between ATOS components. During the CAAA and maritime demonstrations, the assessment team observed interoperability problems between the HHR and RCU. The assessment team observed that the HHR did not work while the RCU was interrogating RF tags. One HHR would lock up if another HHR were in close proximity.

MOP 1.3.15 Half-duplex communications between RF tag, HHR, and RCU

The assessment team observed a few problems with data transfer between HHR and PP. During the maritime demonstration on the USS Harry S. Truman, the system was not successful in transferring 180 transaction records from the HHR to the PP. In addition, ATOS was not successful in transferring an inventory list that contained data from 200 RF tags from the PP to the HHR.

MOP 1.3.16 Operator/SME assessment of their ability to change the RF tag user-selectable temperature limit from HHR

The questionnaire responses indicated changing the RF tag user-selectable temperature was acceptable and easy using the HHR (**Figure D-10**).

> *"Easy to do it!"*
>
> USS Harry S. Truman warfighter

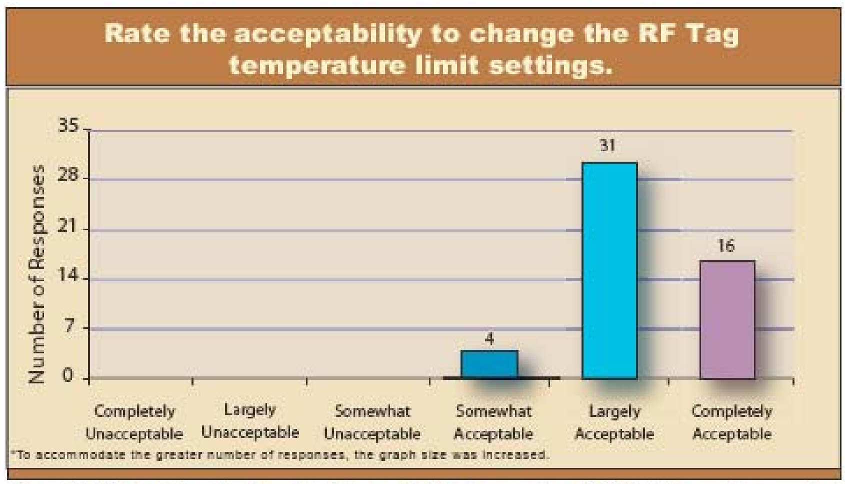

Figure D-10. Questionnaire Results, Change RF Tag Temperature Limit Settings: All respondents agreed that changing the RF tag temperature limits using the HHR was acceptable.

MOP 1.3.17 Operator/SME assessment of their ability to change RF tag user-selectable relative humidity limit from HHR

Questionnaire responses indicated changing the RF tag user-selectable RH limit was acceptable and easy using the HHR (**Figure D-11**).

> *"No problems in changing limits."*
>
> Mieseau warfighter

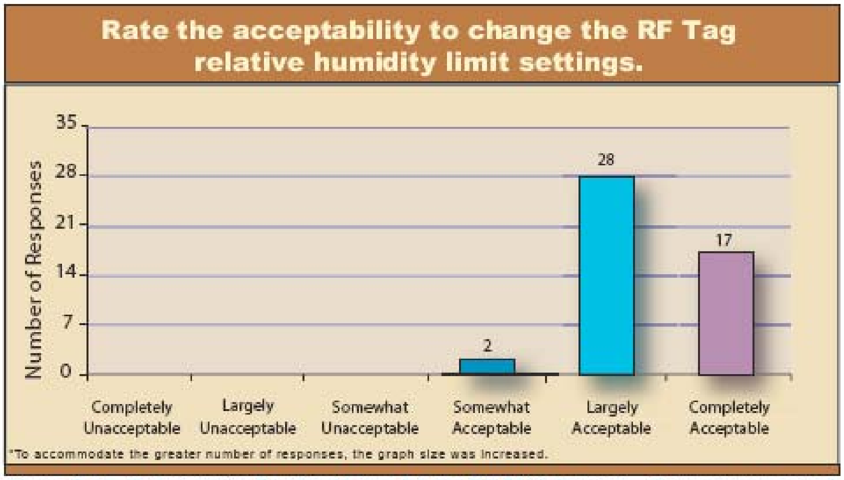

***Figure D-11. Questionnaire Results, Change RF Tag RH Limit Settings:** All respondents agreed that changing the RF tags' RH limits using the HHR was acceptable.*

MOP 1.3.18 Operator/SME assessment of the reader capability to obtain RF tag unique ID number

Questionnaire responses indicated obtaining the RF tag unique ID number using the HHR was effective (**Figure D-12**). Logistics and munitions SMEs indicated that the HHR would sometimes have difficulty picking up the RF tag ID number from the HHR but would eventually read it. One logistics SME stated, "*I think the capability is there but needs some improvement [in] this area.*"

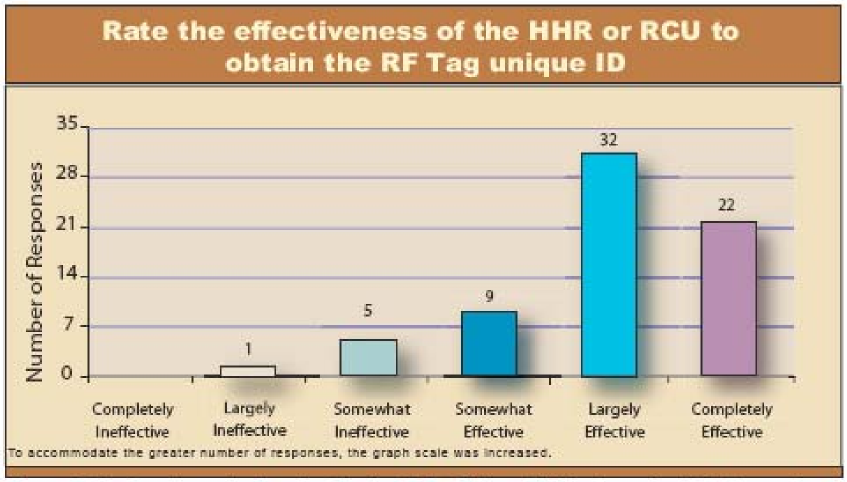

Figure D-12. Questionnaire Results, Obtain RF Tag Unique ID Number: *63 of 69 of respondents agreed that using the HHR or RCU to obtain the RF tag's unique ID was effective.*

MOP 1.3.19 Operator/SME assessment of RF tag/reader communications

Questionnaire results indicated that the HHR and RCU were acceptable for transferring RF tag data despite technical problems encountered during the demonstrations. Although the results were positive (**Figure D-13**), the warfighters complained that the read and write processing speed of the HHR needs improvement.

> *"Process slow at times. HHR had problems in reading RF tags."*
>
> Warfighters

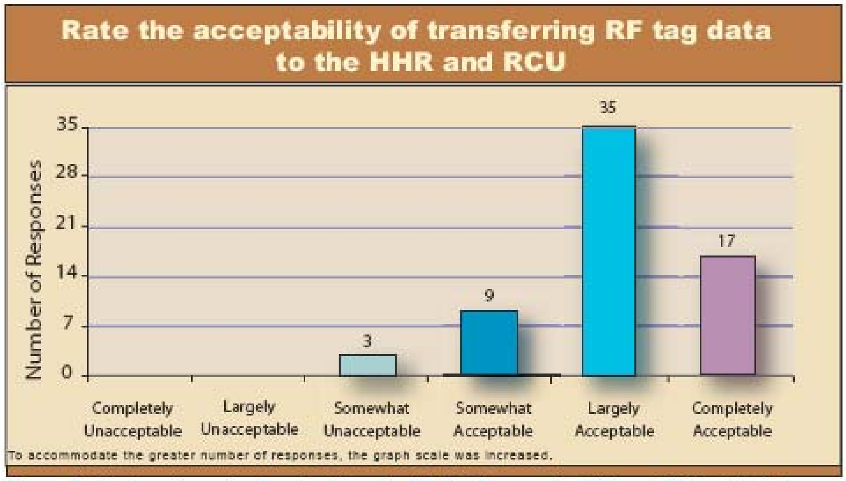

Figure D-13. Questionnaire Results, Transfer RF Tag Data to the HHR and RCU: 61 of 64 respondents agreed that the HHR or RCU was acceptable for transferring RF tag data.

MOE 1.4 Capability of ATOS HHR and RCU to communicate and transfer data to PP

This MOE assesses the capability of the RCU and HHR to transfer stored RF tag data to the PP. During pallet receipt, the HHR was not able to transfer a large number of transaction records (i.e., 180 out of 200 transaction records) to the PP, as the HHR software would lock up after a couple minutes. During the CAAA demonstration, the assessment team observed that when the warfighters docked the HHR, some transaction records did not get transferred to the PP and other transaction records were deleted from the HHR. To resolve the problem, the TM reduced the number of transaction records that were transmitted to the PP to only 50 transaction records at a time.

MOP 1.4.1 Percentage of HHRs that were able to transfer data to PP

During the Miesau demonstrations, all four HHRs transferred transaction records to the PP during pallet receipt. The assessment team compared the count of the handwritten inventory list to the count of the PP inventory list. This comparison was accomplished at all demonstration sites.

During the CAAA demonstration, all three HHRs transferred transaction records to the PP during pallet receipt. The assessment team observed technical problems with the data transfer of transaction records from the HHR to the PP. This was the first time the assessment team observed a problem with the RF tags having corrupted serialized data on the RF tags, which required the TM to purge the PP database.

During the demonstration onboard the USS Ponce, all three HHRs transferred transaction records to the PP during pallet receipt. A total of 60 out of 60 transaction records were successfully transferred to the PP.

Four HHRs were taken to the demonstration onboard the USS Harry S. Truman; however one of the four HHRs was not fully charged and therefore not available for assessment. Of the three remaining HHRs, all were able to transfer records to the PP during pallet receipt. During this demonstration, the assessment team learned that the HHR was not able to transfer 180 transaction records to the PP. The TM developed a work around solution to transmit smaller packets (50 transaction records per packet) to the PP, and these transmissions were successful. One warfighter stated, *"There were still some glitches in download process. Data transfer/writing capabilities are sluggish. Would like to have faster processing of information."* **Figure D-14** shows responses to the effectiveness of data transfer from the HHR to PP.

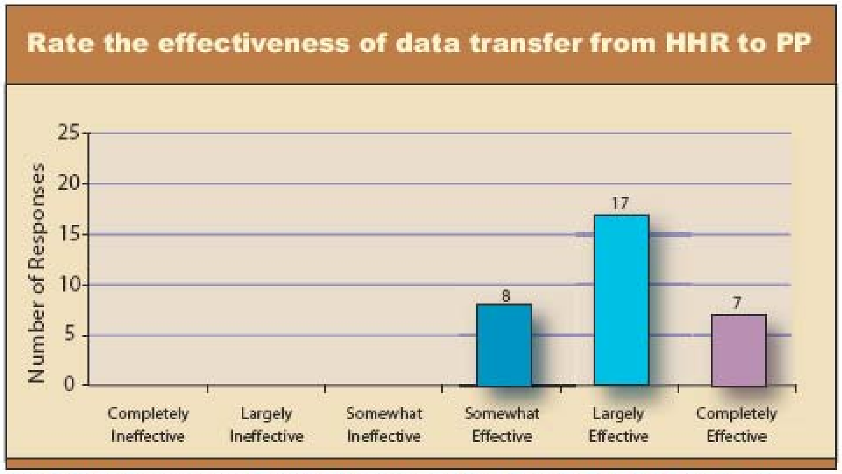

Figure D-14. Questionnaire Results, Effectiveness of Data Transfer from HHR to PP: All respondents agreed that the data transfer from the HHR to the PP was effective.

Figure D-15 shows responses to the questionnaire statement about ATOS supporting data transfer from HHR to PP.

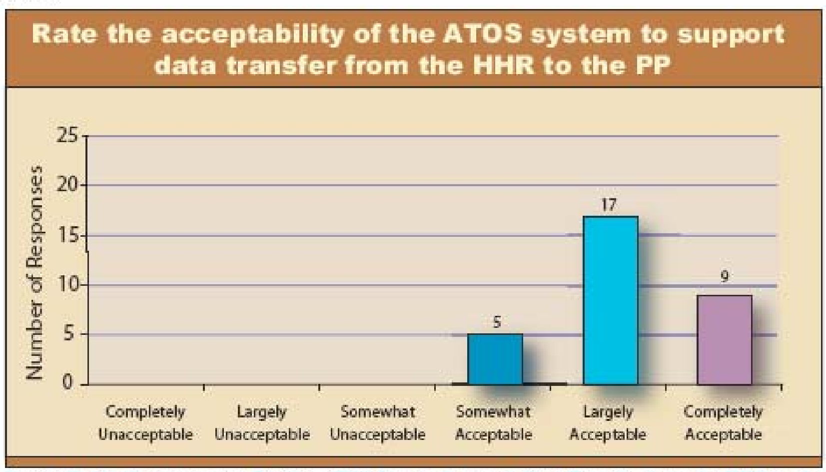

Figure D-15. Questionnaire Results, ATOS System Supports Data Transfer from the HHR to the PP: All respondents agreed the HHR to the PP transfer was acceptable.

MOP 1.4.2 Percentage of RCUs that were able to communicate and transfer data to PP.

Both RCUs used during the Miesau demonstration were able to communicate data to the PP. The RCU in the earth-covered magazine transferred interrogated RF tag data to the PP via WLAN. The second RCU transferred data via a serial port. This RCU had a data transfer problem when communicating with the HHR, which was resolved by a software change. The assessment team observed the transfer of the interrogated RF tag data to the PP by using the HHR and verified that the PP inventory matched the list of RF tags placed inside the test site. The assessment team also verified the pallet count changes were updated on the PP.

Two RCUs were used in the CAAA demonstration. One RCU was installed in an earth-covered magazine and the other was installed in a storage warehouse. Both RCUs were connected to a PP via WLAN and both were successful in transferring interrogated RF data to the PP. The assessment team verified that the PP inventory matched the list of RF tags placed inside the test sites and that the pallet count changes were updated on the PP.

One RCU was used in the maritime demonstration on the USS Harry S. Truman, and was successful in transferring interrogated RF tag data to the PP via a LAN. The assessment team verified that the PP inventory matched the list of RF tags placed inside the test site and the pallet count changes were updated on the PP. Most of the warfighters indicated, "*Slow processing speed does not always pick up the RF tag information. Overall, it seems, to work ok.*" **Figure D-16** shows responses to the questionnaire statement about data transfer for several RF tags to the RCU and PP.

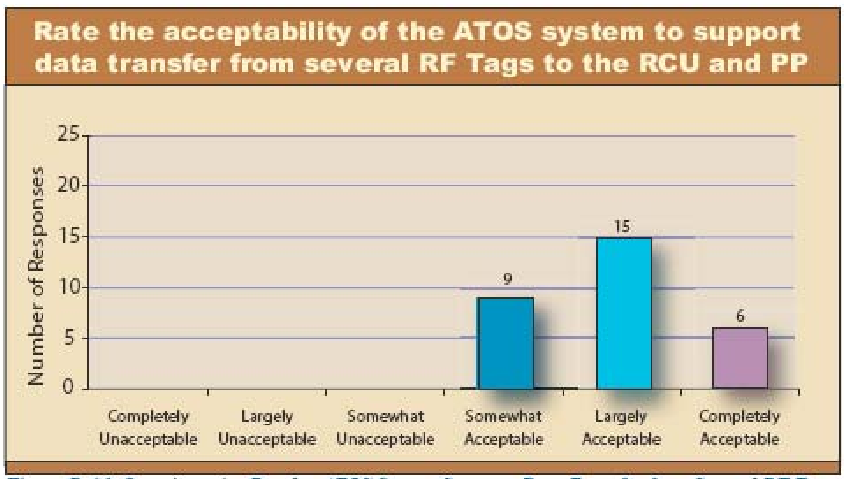

Figure D-16. Questionnaire Results, ATOS System Supports Data Transfer from Several RF Tags to the RCU and PP: *All respondents agreed the data transfer of the RF tags to the RCU and PP was acceptable.*

MOP 1.4.3 SME assessment of HHR-PP connectivity

Questionnaire responses indicated that the HHR-to-PP connectivity was usable during the demonstrations (**Figure D-17**); however, the assessment team observed several data transfer problems during pallet receipt. One warfighter stated, "*[It] seems when docking the HHR there was some problems with data transfer.*" Although the HHR-to-PP data transfer process was usable, the warfighters stated it needed improvement.

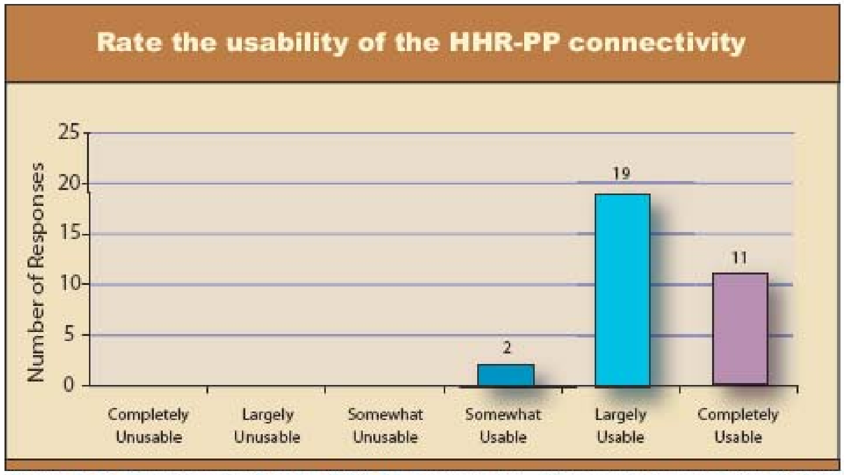

***Figure D-17. Questionnaire Results, HHR-PP Connectivity:** All respondents agreed that the HHR-PP connectivity was usable.*

MOP 1.4.4 WLAN transmitter radiation parameters

The WLAN power was 100mW effective isotropic radiated power, which meets the HERO requirement for a COTS product.

MOP 1.4.5 WLAN transmitter frequencies

The WLAN transmitter frequency was 2.5 Gigahertz.

MOP 1.4.6 Detection range for WLAN between RCU and PP

At the Miesau demonstration, a line-of-sight connection was established with the RCU inside the earth-covered magazine and the PP, which was located an eighth of a mile away. The assessment team did not observe any issues with RCU and PP connectivity using the WLAN.

At the CAAA demonstration, two WLANs were installed at the test sites. The first WLAN required a repeater on top of a 75-foot water tower to establish a 1.5 mile connection to the PP. The second WLAN was a line-of-sight connection that was less than 0.5 miles away from the PP. At both test sites, the WLAN was able to provide reliable connectivity from the RCU to the PP throughout the demonstration.

MOP 1.4.7 Operator assessment of HHR, RCU, and PP communication and data transfer interface

Questionnaire responses indicated the communications and data transfer interface between the HHR, RCU, and PP was acceptable for the demonstrations (**Figure D-18**); however, most of the warfighters believed the data transfer interface between the HHR, RCU, and PP needs improvement.

> *"Still needs [sic] 100% assurance that the HHR will work with the PP."*
>
> Crane Warfighter

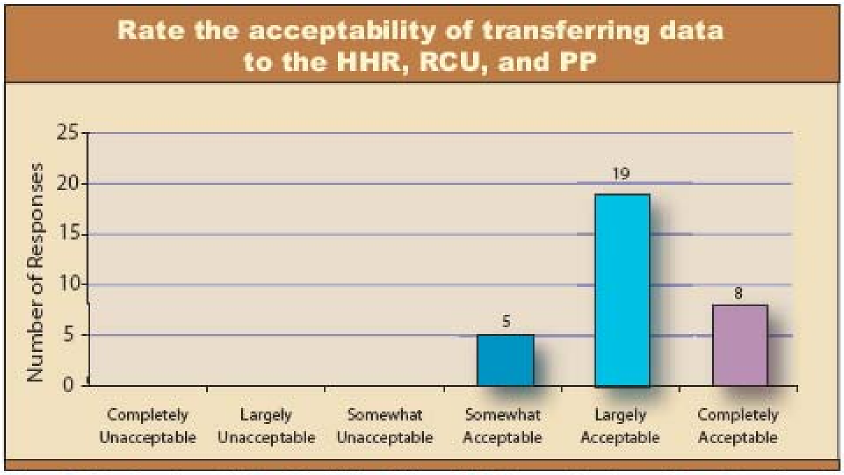

***Figure D-18. Questionnaire Results, HHR, RCU, and PP Communication and Data Transfer:** All respondents agreed that the HHR, RCU, and PP connectivity was acceptable.*

MOE 1.5 Capability of ATOS PP to interoperate with Service Ammunition AIS

This MOE was not assessed because the Service Ammunition AIS was not available during the demonstrations.

MOE 1.6 Capability of ATOS PP to interoperate with EDB

This MOE was not assessed because the EDB was not available during the demonstrations.

MOE 1.7 Characterization of network bandwidth connectivity to ATOS PP

This MOE assesses the data connectivity of the PP from the HHR and RCU. The HHR docking station was connected to the PP by an Ethernet connection. A LAN or a WLAN were used to connect the RCU to the PP. During the Miesau, CAAA, and maritime demonstrations, the assessment team did not observe any network bandwidth problems that would impact data transfer from the RCU to the PP or from the HHR and PP.

MOP 1.7.1 Bandwidth between HHR and PP

The HHR docking station was connected to the PP by an Ethernet connection. The bandwidth was 250 Megabytes (MB)/second. When the HHR was placed into the docking station, the data were automatically downloaded to the PP. As stated earlier, the TM needed to fix the software on the HHR and PP to resolve data transfer problems encountered during the demonstration. The assessment team did not observe any data transfer problems involving network bandwidth.

MOP 1.7.2 Bandwidth between RCU and PP

The assessment team observed no problems with network bandwidth between the RCU and PP. The TECEVAL data revealed the WLAN bandwidth was 10 MB/second, which is the commercial standard for a WLAN; and 250 MB/second via Ethernet connection.

MOP 1.7.3 Operator assessment of bandwidth between HHR and PP

The operators had insufficient knowledge to assess bandwidth. The assessment team did not collect any bandwidth data during the demonstration.

MOP 1.7.4 Operator assessment of bandwidth between RCU and PP

The operators had insufficient knowledge to assess bandwidth. The assessment team did not collect any bandwidth data during the demonstration.

MOE 1.8 Capability of ATOS system to protect data

The assessment team was unable to assess network security since a security SME was not available during the demonstrations.

MOE 1.9 Capability of ATOS system to provide sufficient data storage

This MOE assesses the data storage capability of the HHR, RCU, and PP. The assessment team did not observe any data storage issues with ATOS during the demonstrations. The HERO requirements for the demonstrations restricted the number of RF tags that could be used to support the assessment; as a result, only 200 RF tags could be used for each test facility per demonstration.

MOP 1.9.1 HHR storage memory capacity

The HHR storage memory capacity was 64 MB of read-only memory and 64 MB random-access memory. The assessment team did not observe any data storage issues during the demonstrations.

MOP 1.9.2 RCU storage memory capacity

The RCU storage memory capacity was 256 MB. The assessment team did not observe any data storage issues during the demonstrations.

MOP 1.9.3 PP storage memory capacity

The PP storage memory capacity was based on the laptop computer hard drive storage capacity, which was over 40 Gigabytes. PP storage capacity was never an issue during the demonstrations.

MOP 1.9.4 SME assessment of RF tag data storage

Questionnaire results indicated the warfighters believed the RF tag data storage was usable and adequate to support munitions management (**Figure D-19**). Most of the warfighters agreed that having RF tags with large memory would be useful for changing and storing additional information about the tagged munitions pallets.

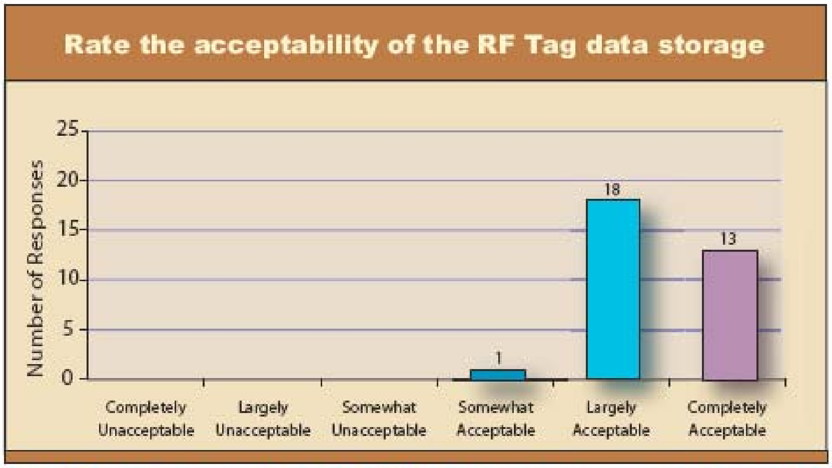

Figure D-19. Questionnaire Results, RF Tag Data Storage: All respondents agreed that the RF tag data storage was acceptable.

MOP 1.9.5 SME assessment of data storage for HHR and RCU

Questionnaire results indicated the SMEs believed the HHR and RCU data storage was usable and adequate to support munitions management (**Figure D-20**). ATOS data storage capacity was never exceeded during any of the demonstrations.

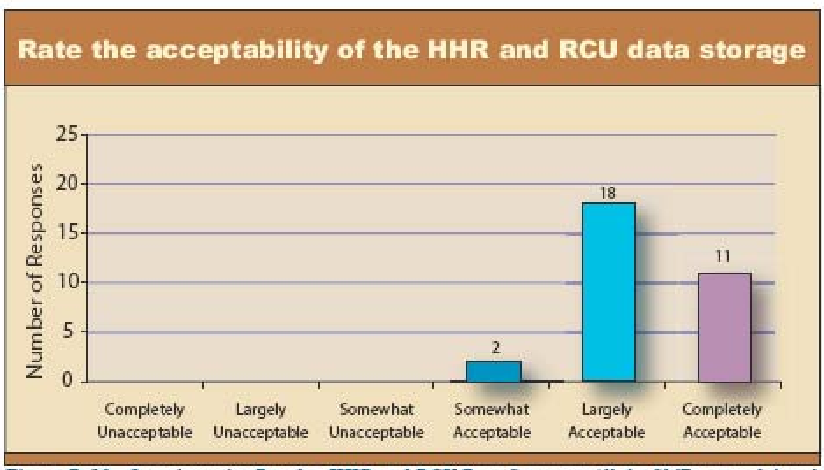

Figure D-20. Questionnaire Results, HHR and RCU Data Storage: All the SMEs agreed that the HHR and RCU data storage was acceptable.

MOP 1.9.6 SME assessment of PP data storage

The questionnaire results indicated that the PP data storage was usable and adequate to support munitions management at the Miesau and CAAA demonstrations (**Figure D-21**). Only the accountable record managers responded to this questionnaire statement.

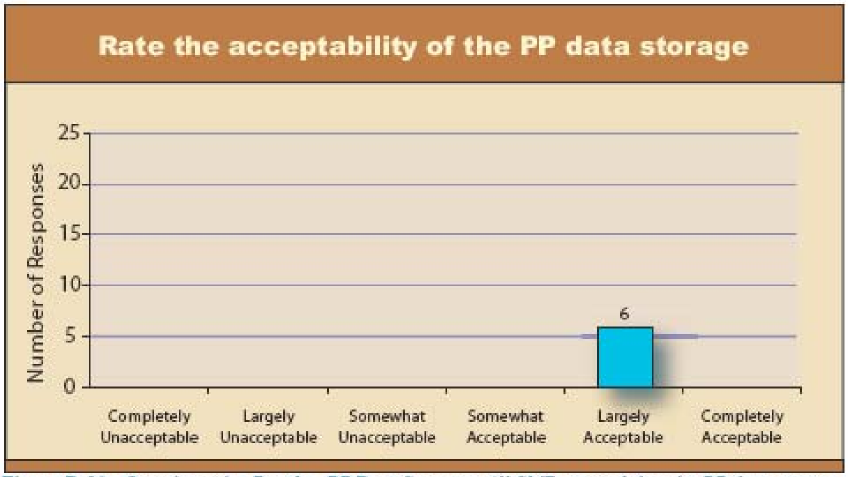

***Figure D-21. Questionnaire Results, PP Data Storage:** All SMEs agreed that the PP data storage was adequate.*

MOE 1.10 Characterization of ATOS RCU antenna coverage

This MOE assesses antenna coverage of the RCU inside an earth-covered magazine, storage warehouse, or shipboard magazine. The RCU and RFE were effective in providing adequate antenna coverage to detect 200 RF tags during the demonstrations.

During the first interrogation cycle at the Miesau demonstration, the RCU detected 199 out of 200 RF tags (99.5%) in a 60 x 40 x 15 foot earth-covered magazine with three RFEs; 169 out of 174 tags (97.1%) in a 70 x 200 foot ASP with eight RFEs. During the second and third interrogation cycles, the RCU detected 100% of the RF tags. The warfighters expressed some concerns about the application of ATOS in an ASP. One Miesau warfighter stated, "*For an enclosed location the system seems to work well. The problem I see is in what was described as the ASP application. In an open area, the requirement could be extensive, depending on the size of the area to be covered.*" Another concern is that a 'ring of antennas' around a storage area may not be possible due to terrain restrictions.

During the CAAA demonstration, the RCU detected 197 out of 200 tags (98.5%) in both the 100 x 50 x 10 foot earth-covered magazine using 6 RFEs and the 200 x 50 foot storage warehouse using 12 RFEs. During the maritime demonstration, the RCU detected 60 out of 60 RF tags (100%) in a 10 x 22 x 8 foot magazine on the USS Ponce and 200 out of 200 RF tags (100%) in a 45 x 80 x 10 foot magazine using 3 RFEs on the USS Harry S. Truman.

MOP 1.10.1 Antenna coverage between RCU and RF tag

During all demonstrations, the RCU detected approximately 98% of the RF tags on the first interrogation cycle, and 100% after two or three interrogation cycles.

MOP 1.10.2 Operator/SME assessment of antenna coverage between RCU and RF tag

Questionnaire results indicated that the RCU and RFEs were acceptable and provided adequate antenna coverage inside the magazine (**Figure D-22**).

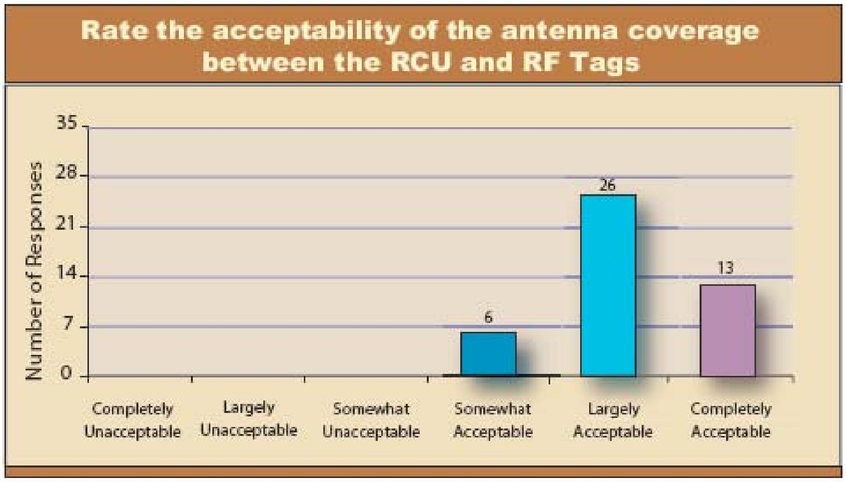

Figure D-22. Questionnaire Results, Antenna Coverage between the RCU and RF Tag: All respondents agreed that the antenna coverage was acceptable during the demonstrations.

MOE 1.11 Capability of ATOS RCU to detect RF tags at initial startup

This MOE assesses the performance of the initial detection of the RF tags by the RCU. During the Miesau and CAAA demonstrations, the RCU was able to detect more than 97% of 200 RF tags, and during the maritime demonstration detected 100% of 200 RF tags.

MOP 1.11.1 Initial RF tag detection using RCU within 145 minutes

The ATOS system was able to detect over 97% of the RF tags within 14 minutes of the first interrogation cycle during the operational demonstrations. At the Miesau demonstration, the first RCU detected 199 out of 200 RF tags (99.5%) during the first interrogation and the ASP RCU detected 194 out of 200 RF tags (97.1%). At the CAAA demonstration, the RCU detected 197 out of 200 RF tags (98.5%) during the first interrogation inside the earth-covered magazine and storage warehouse. At the maritime demonstration on the USS Harry S. Truman, the RCU detected 200 out of 200 RF tags during the first interrogation inside the ship magazine.

MOP 1.11.2 Initial RF tag detection using RCU within 215 minutes

Not assessed. The assessment team was not able to verify missing or new RF tags were detected within 215 minutes based on how the ATOS system interrogates RF tags using the short and long read cycles.

MOE 1.12 Usability of ATOS HHR input devices

This MOE assesses the operators' ability to use the keypad and stylus to input data on the HHR. During all demonstrations, the operators were able to use the HHR keypad and stylus to input asset data. Most of the operators preferred using the liquid crystal display (LCD) keypad rather than the HHR keypad to input asset data. Even when wearing bulky gloves, the operators were able to edit asset information and perform the munitions management tasks using the HHR keypad.

MOP 1.12.1 HHR keypad input.

The questionnaire responses indicate that the HHR keypad was usable to all the respondents (**Figure D-23**). During pallet receipt, pallet transfer, and inventory maintenance, warfighters preferred to use the LCD keypad and stylus to input asset information data on the HHR. Questionnaire responses indicated the HHR keypad was usable for data entry (**Figure D-24**).

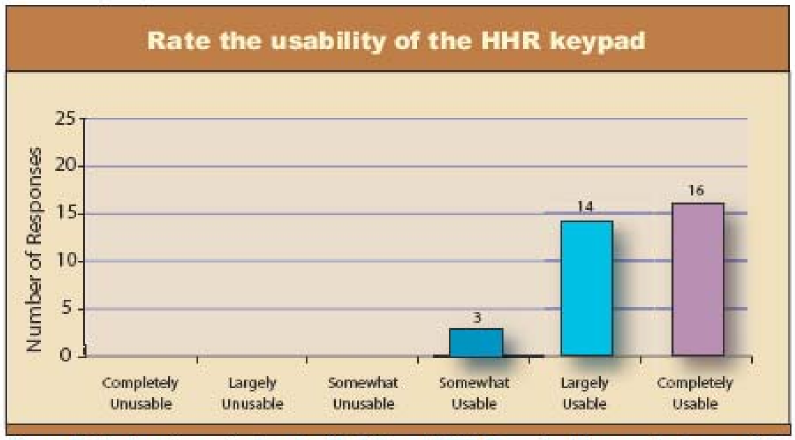

Figure D-23. Questionnaire Results, Usability of HHR Keypad: All respondents agreed that the HHR keypad was usable.

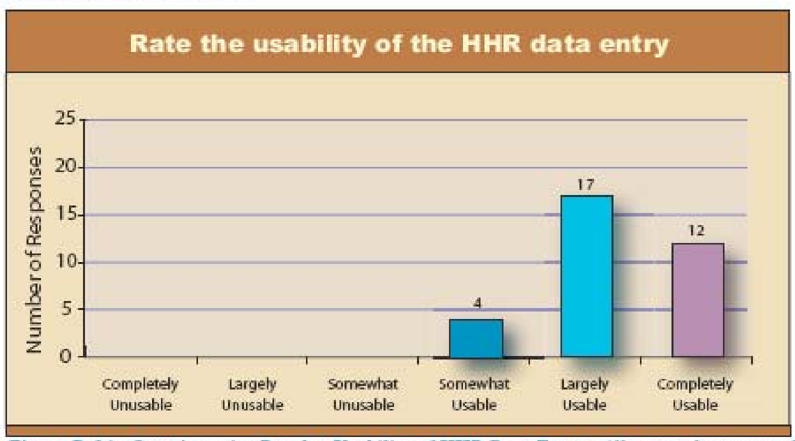

Figure D-24. Questionnaire Results, Usability of HHR Data Entry: All respondents agreed that the HHR was usable for data entry.

MOP 1.12.2 HHR stylus input

The warfighters were able to use the stylus to input asset information (**Figure D-25**) and they found it especially useful when wearing bulky gloves.

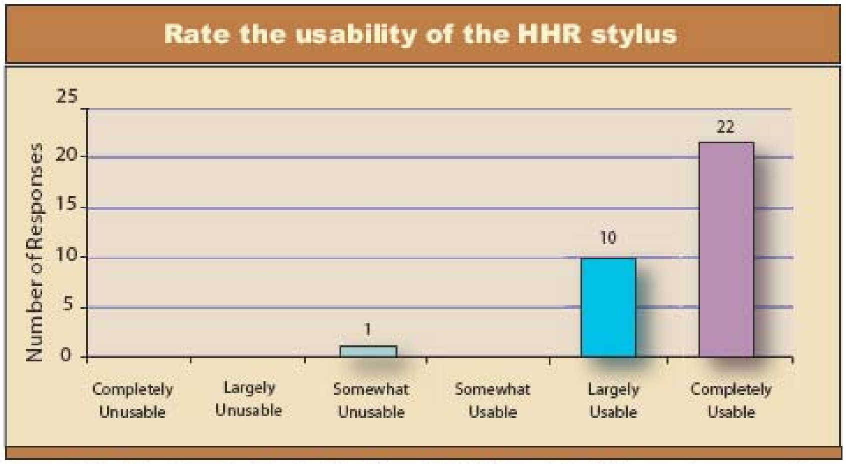

***Figure D-25. Questionnaire Results, Usability of HHR Stylus:** 32 of 33 respondents agreed that the HHR stylus was usable.*

MOE 1.13 Capability of ATOS HHR to create RF tags and barcodes

This MOE assesses the capability to use the HHR to create new RF tags and barcodes. During the demonstration, the HHR was not used to create barcodes. Instead, the barcode template was created by the TM using a barcode machine. Warfighters were able to use the HHR to input asset information on new RF tags using barcode templates. Most of the warfighters believed the process was easy and straightforward, although some complained that it took two to five minutes to transfer asset data from the HHR to the RF tag.

> *"Very easy!"*
>
> Mieseau Warfighter

MOP 1.13.1 HHR creation of new RF tags

At each demonstration site, the warfighters were given 20 RF tags to create. The warfighters were able to quickly populate the RF tags with asset data. Questionnaire responses indicated that creating a new RF tag using an HHR was acceptable (**Figure D-26**). The two unacceptable comments did not provide any system improvement information.

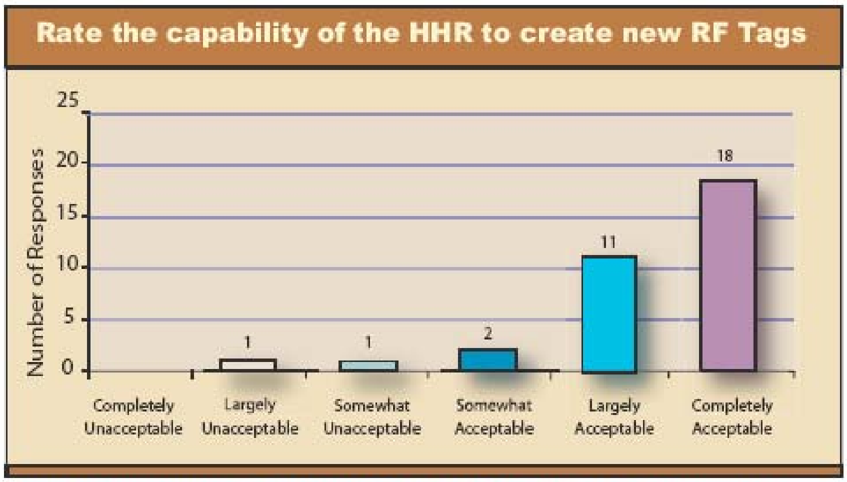

***Figure D-26. Questionnaire Results, HHR Creation of New RF Tags:** 31 of 33 respondents agreed that using the HHR to create new RF tags was acceptable.*

MOP 1.13.2 HHR creation of replacement RF tags

At each demonstration site, warfighters replaced five RF tags using the HHR. The warfighter was able to transfer the asset information from the old RF tag to the replacement RF tag using the HHR. Questionnaire responses indicated that creating a replacement RF tag using an HHR was acceptable (**Figure D-27**).

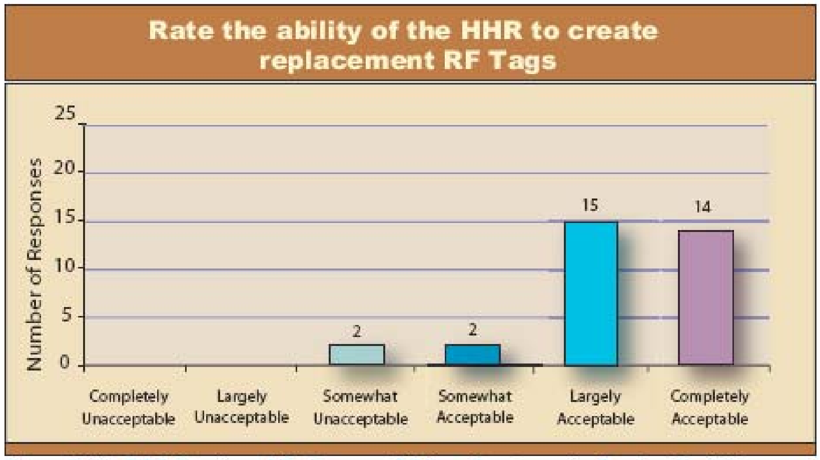

***Figure D-27. HHR Creation of Replacement RF Tags Questionnaire Results:** 31 of 33 respondents agreed that using the HHR to create replacement RF tags was acceptable.*

MOP 1.13.3 HHR creation of barcodes

Not assessed. The capability was not used during the ACTD.

MOE 2.1 Reliability of ATOS RF tag attachment

This MOE assesses the RF tag attachment method used during the demonstrations. During the Miesau and CAAA demonstrations, the RF tags were not attached to the munitions pallets but were placed on the side or on top of the munitions pallets. A limited assessment was conducted by placing the RF tag holders on one wooden pallet and one metal pallet. Two methods were used to attach the RF tags on the wood and metal munitions pallets. The first method used wood screws to attach the tag holder, while the second method used a special double-sided adhesive tape. The adhesive tape was very effective on metal pallets. Although the adhesive tape was used on a wooden pallet, the warfighters recommended that wood screws be used to secure the tag holder.

TECEVAL data revealed that the RF tag could be easily separated from the tag holder if a mass of 790 grams was placed on top of the RF tag. A similar shear force from either side or the bottom also would cause the RF tag to separate from the holder. Although the RF tags remained in place during the demonstrations, one warfighter stated, "*The RF tags needed a magnetic interface to put up a flag when RF tag is removed from tag holder. This would eliminate questionable moves.*"

MOP 2.1.1 Reliability of attachment method

Insufficient data were collected to assess the reliability of the attachment method used to attach the tag holder to the munitions pallet during transport.

MOP 2.1.2 Reliability of RF tag attachment

Insufficient data were collected to assess the reliability of the RF tag remaining attached to the tag holder during transport.

MOP 2.1.3 Operator assessment of RF tag attachment and attachment method

Questionnaire responses indicated tag attachment and attachment methods were acceptable, but needed some improvement (**Figure D-28**). One USS Harry S. Truman warfighter felt the RF tag holder should be made out of the pallet material to improve durability. Three CAAA warfighters did not like the idea of using adhesive tape to attach the RF tag holders to a wooden box or munitions pallets. Warfighters strongly recommended using wood screws to secure the RF tag holders to the wooden box or pallets to prevent the tag holder from being pulled off during transport.

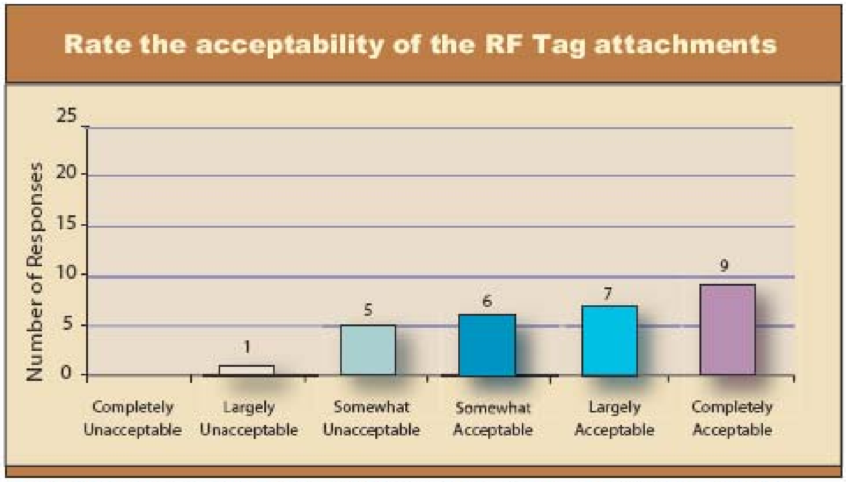

Figure D-28. Questionnaire Results, RF Tag Attachment and Attachment Method: *22 of 28 respondents agreed that the RF tag attachment and attachment method were acceptable.*

MOE 2.2 Usability of ATOS HHR and RCU

This MOE assesses the usability of the HHR display, HHR data entry, HHR docking station capability, and the RCU-PP bridging using the Ethernet connection. The warfighters felt the HHR and RCU were easy to use and operate, and a time-saver for managing the movement and shipment of munitions pallets. One Miesau warfighter stated that, *"Once the HHR is fixed, the HHR should be highly usable and user friendly."* An operator stated, *"Display is user friendly."* The warfighters were able to download a partial inventory list of 20 to 60 RF tags from the PP to the HHR. The HHR was taken to the magazine or storage location to conduct the inventory and identified new or missing tagged pallets within 15 minutes. During the demonstrations, the assessment team observed one data transfer problem with the HHR-RCU bridging capability and two data transfer problems with the HHR-PP bridging capability involving transmission of 200+ RF tag data records. The HHR-RCU bridging was resolved by a software fix and demonstrated at CAAA. The HHR-PP data transfer problem occurred during the maritime demonstration. This problem raised some concerns about accuracy of the inventory list during the data transfer process. The warfighters also expressed some concerns about the HHR processing time for reading and writing data to the RF tags. All warfighters felt it took a long time to process an RF tag.

MOP 2.2.1 HHR display usability

The warfighters felt the HHR display was user friendly and easy to use (**Figure D-29**).

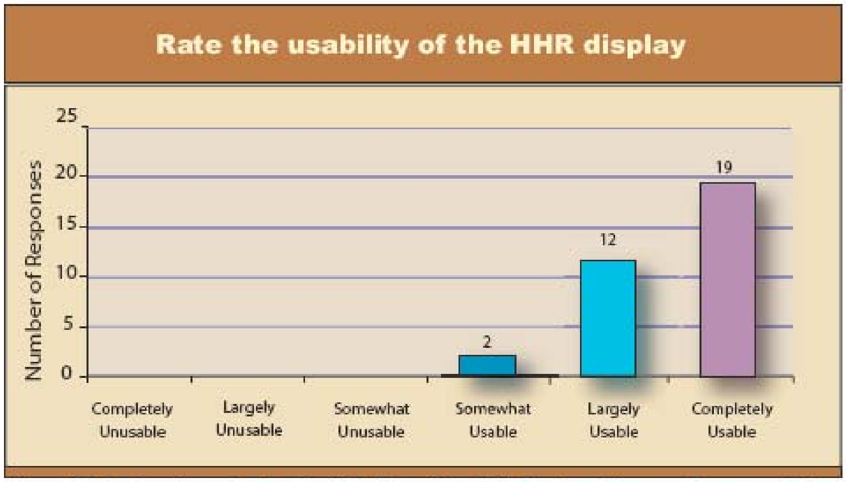

Figure D-29. Questionnaire Results, Usability of the HHR Display: *All respondents agreed that the HHR display was usable.*

MOP 2.2.2 HHR input usability

The warfighters stated the HHR data entry was easy (**Figure D-30**). Reference MOP 1.12.1 for the results.

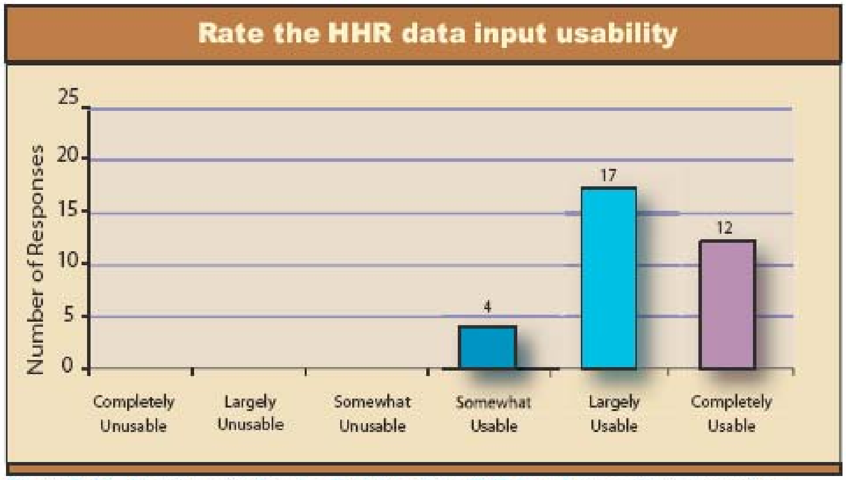

Figure D-30. Questionnaire Results, Usability of the HHR Data Input: *All the respondents agreed about the usability of the HHR to input data.*

MOP 2.2.3 HHR-RCU bridge usability (Ethernet connection)

> *"Need to be able to view RCU download at building by RF tag ID number, DODIC and NSN."*
>
> Crane Warfighter

After the TM fixed the software bugs, the HHR and RCU bridge worked well in transferring data from the RCU to the HHR during the CAAA demonstration. The questionnaire responses indicated the HHR-RCU bridge was usable to support munitions management (**Figure 31**). The unusable comments came from the Miseau demonstration. These comments did not provide any system improvement information.

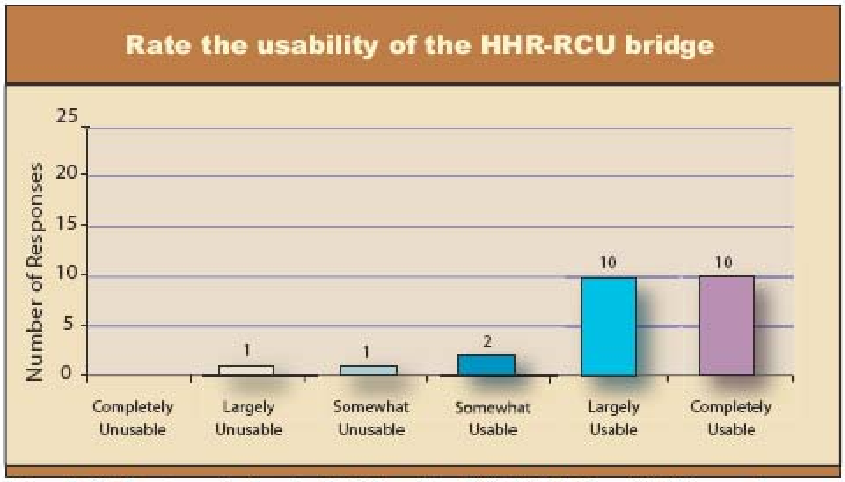

Figure D-31. Questionnaire Results, Usability of the HHR-RCU Bridge: 22 of 24 respondents agreed that the HHR-RCU bridge was usable.

MOP 2.2.4 HHR-PP bridge usability

The assessment team observed data transfer problems with the HHR-PP bridge. During the maritime demonstration, the HHR transferred all the transaction records to the PP during pallet receipt, but the PP did not transfer the inventory list of 200 RF tags to the HHR. During the Miesau and CAAA demonstrations, the HHR and PP were successful in downloading data from 20 to 60 RF tags. Questionnaire responses indicated the HHR-PP bridge was usable (**Figure D-32**).

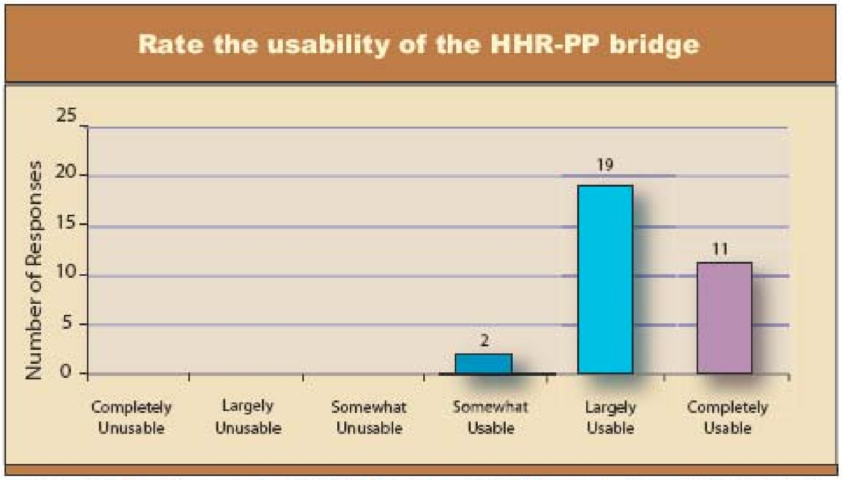

***Figure D-32. Questionnaire Results, Usability of the HHR-PP Bridge:** All respondents agreed that the HHR-PP bridge was usable.*

MOP 2.2.5 HHR-PP docking station usability

Warfighters were able to dock the HHR and transfer the RF tag data to the PP when ATOS did not encounter data transfer problems (**Figure D-33**).

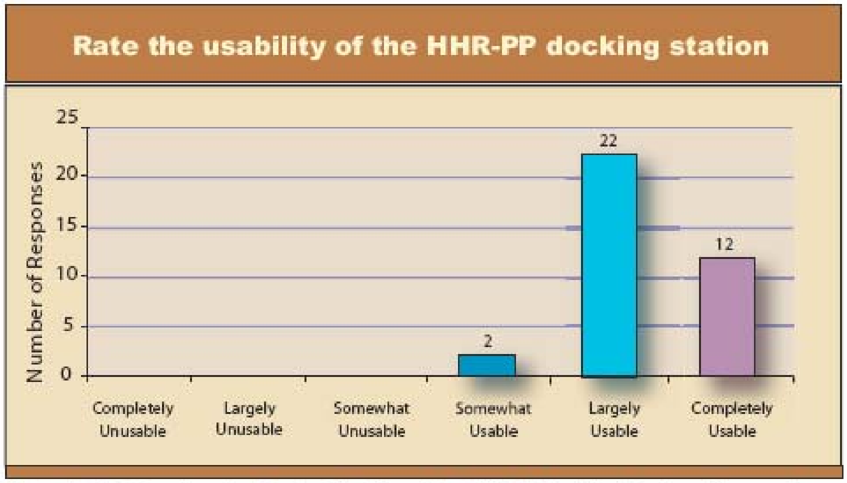

***Figure D-33. Questionnaire Results, Usability of the HHR-PP Docking Station:** All respondents agreed that the HHR-PP docking station was usable.*

MOE 2.3 Usability of ATOS PP

This MOE assesses the PP display and ease of data entry. The warfighters indicated the PP was easy to learn and operate and had user-friendly menus.

MOP 2.3.1 PP display usability

The warfighters indicated the PP display was easy to use to obtain inventory and transaction information (**Figure D-34**).

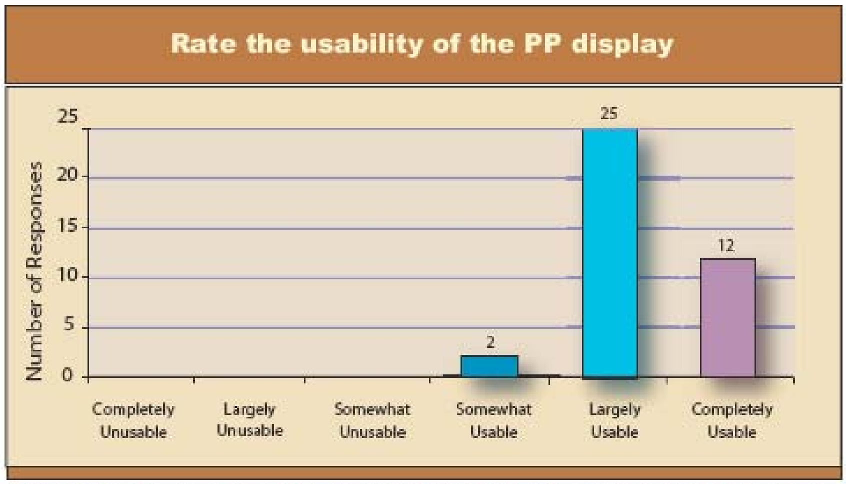

***Figure D-34. Questionnaire Results, Usability of the PP Display:** All respondents agreed that the PP display was usable.*

MOP 2.3.2 PP input usability

The warfighters stated that data entry input using the PP was easy and had user-friendly menus (**Figure D-35**).

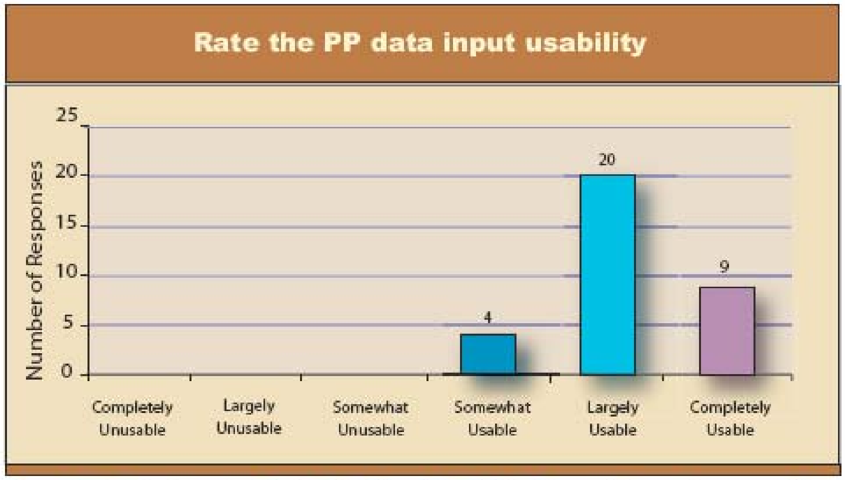

Figure D-35. Questionnaire Results, Usability of the PP Data Entry: *All respondents agreed that using the PP was usable to input data.*

MOE 2.4 Ease of configuration for ATOS components

This MOE assesses the operators' ability to easily configure the RF tags, HHR, RCU, and PP during the demonstration. ATOS components were easy to configure and could be adjusted quickly to meet the warfighter's needs. One warfighter stated, *"[He] had no problem configuring RF tags."* Another warfighter stated, *"The HHR and the PP were easy to learn and have user-friendly software interfaces."* Although most comments were positive about ATOS components, the assessment team received several comments about potential improvements. A Miesau warfighter stated the RF *tags need to be reusable."* Due to the cost of making the RF tag, the warfighter wanted recyclable RF tags. Another CAAA warfighter felt the RF tags should have the capability to read a 1348 barcode (inventory sheet). The warfighter can print a barcode and write directly to the RF tag using an HHR.

MOP 2.4.1 Capability to configure RF tag

> *"It was real simple"*
>
> USS Harry S. Truman warfighter

The warfighters were able to use the HHR to configure the RF tags by entering asset information and adjusting user-selectable environmental settings (**Figure D-36**). The unacceptable comment did not provide any system improvement information. The unacceptable comment did not provide any system improvement regarding the configuration of the RF tags.

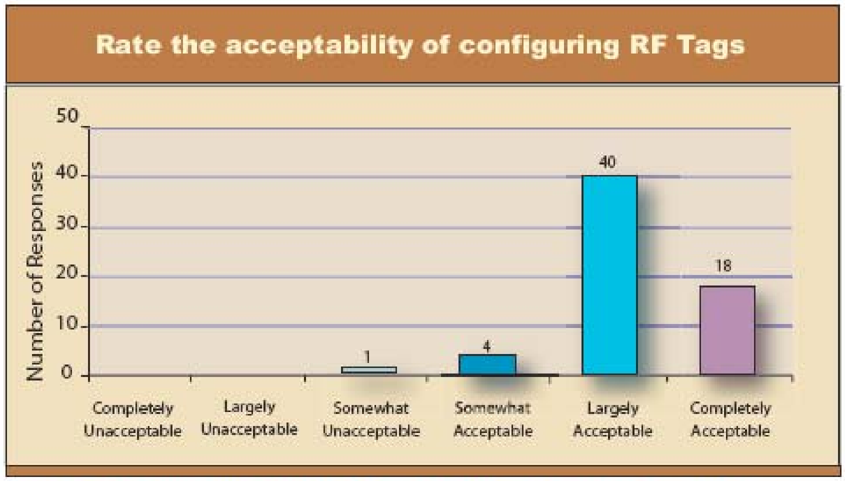

***Figure D-36. Questionnaire Results, Configuring RF Tag:** 62 of 63 respondents agreed that configuring the RF tag was acceptable.*

MOP 2.4.2 Capability to configure HHR

The warfighters were able to quickly configure the HHR to link with the PP (**Figure D-37**). The unacceptable comment did not provide any system improvement information.

> *"Very easy to use and configure"*
>
> Warfighter

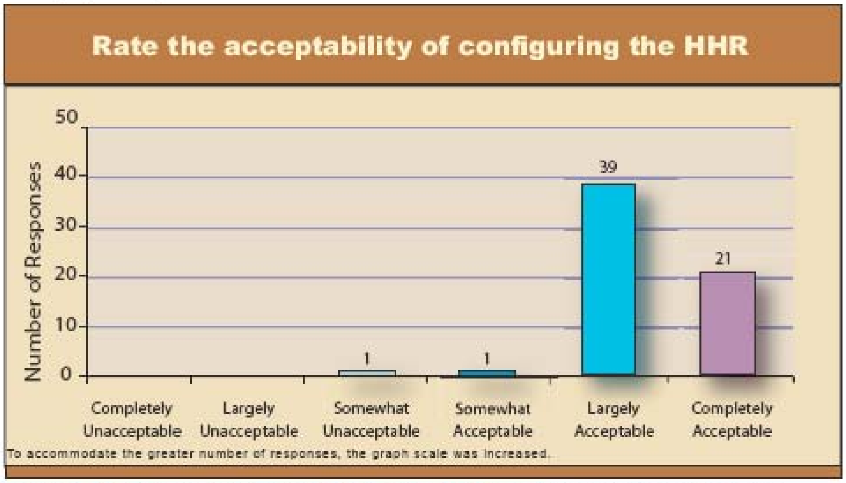

Figure D-37. Questionnaire Results, Configuring HHR: 61 of 62 respondents agreed that configuring the HHR was acceptable

MOP 2.4.3 Capability to configure RCU

The assessment team did not observe the ATOS operators making any configuration changes to the RCU.

MOP 2.4.4 Capability to configure PP

The assessment team did not observe the ATOS operators making any configuration changes to the PP.

MOE 2.5 Adequacy of ATOS training

This MOE assesses the training received at the demonstration sites. The warfighters agreed training was adequate after using ATOS. The training was effective in showing the warfighters how to operate the system. One warfighter stated, *"training was excellent but could be a bit more structured. Try more visual aids (i.e. attach a tag to a pallet/box and go through a pallet transfer and pallet issue.)."* All warfighters wanted an ATOS user's guide and training manual to explain the system operation.

MOP 2.5.1 Training for RF tag

Training was adequate to show the ATOS participants how to use the RF tag (**Figure D-38**).

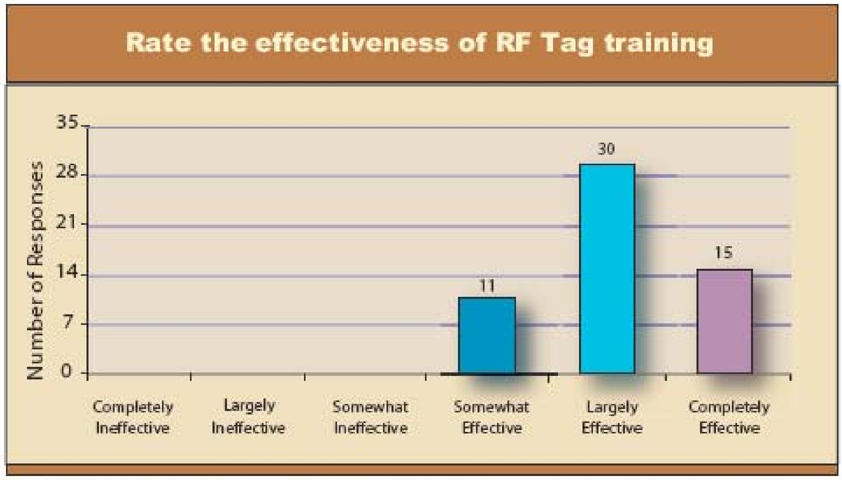

***Figure D-38. Questionnaire Results, RF Tag Training:** All respondents agreed that the RF Training was effective.*

MOP 2.5.2 Training for HHR

Training was adequate to show the ATOS participants how to use the HHR (**Figure D-39**). The ineffective comment was focused on the amount of material presented during the training.

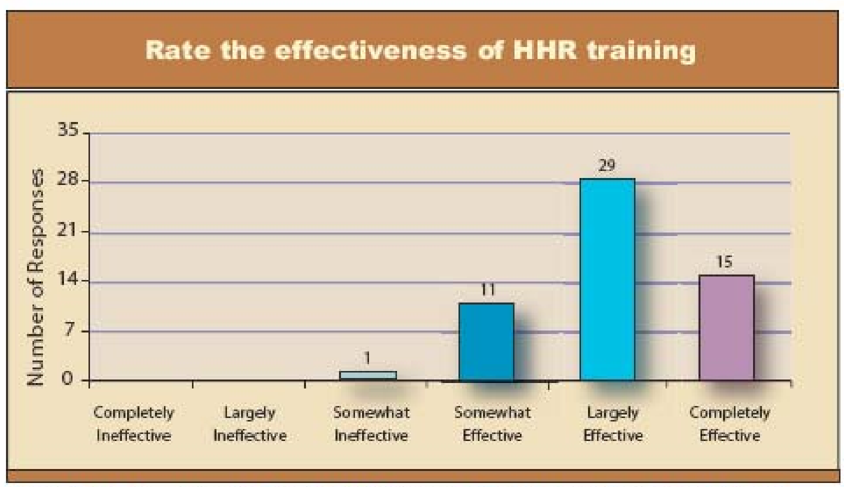

***Figure D-39. Questionnaire Results, HHR Training:** 55 of 56 respondents agreed the HHR training was effective.*

MOP 2.5.3 Training for RCU

Training was adequate to show the ATOS participants how to use the RCU (**Figure D-40**). The ineffective comment was focused on the amount of material presented during the training.

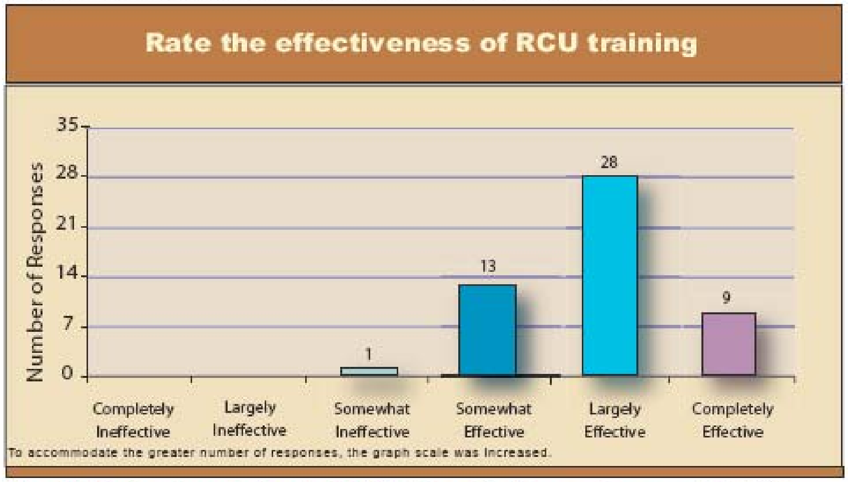

***Figure D-40. Questionnaire Results, RCU Training:** 50 of 51 respondents agreed the RCU training was effective.*

MOP 2.5.4 Training for PP

Training was adequate to show the ATOS participants how to use the PP (**Figure D-41**).

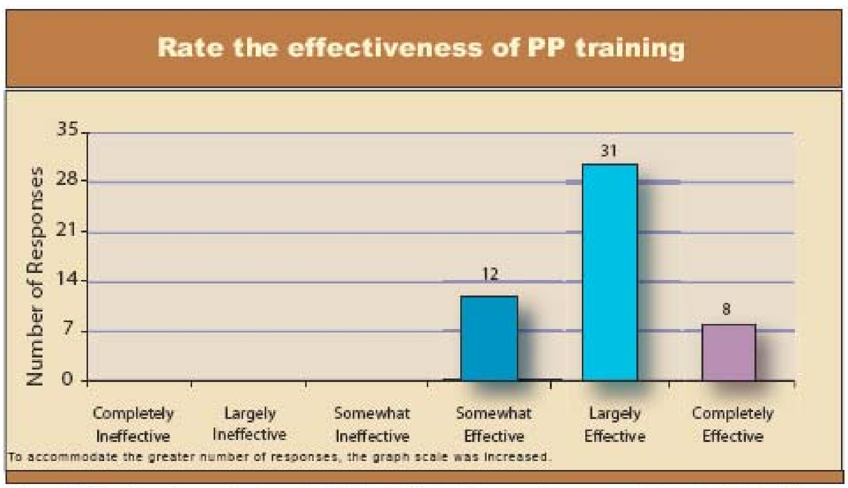

***Figure D-41. Questionnaire Results, PP Training:** All respondents agreed that the PP training was effective.*

MOP 2.5.5 Effectiveness of ATOS training material

The warfighters felt the training was effective in providing the necessary information to operate the ATOS system during the demonstrations (**Figure D-42**). The ineffective comment did not provide any information on improving the training.

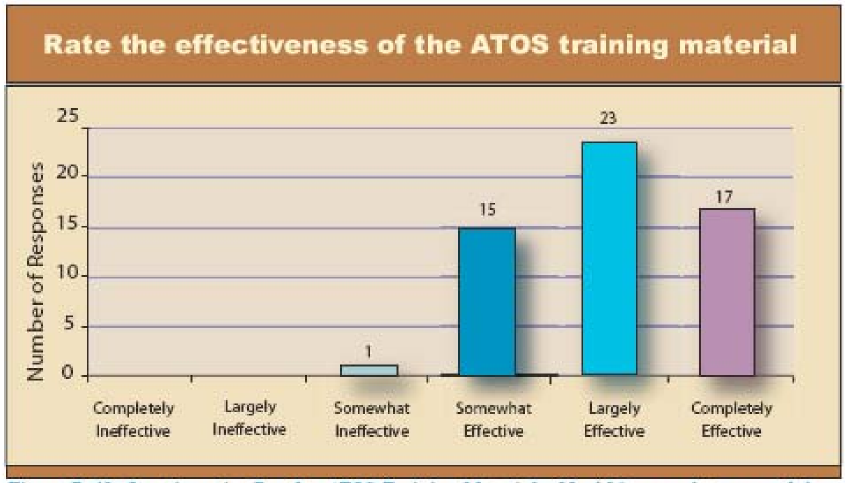

Figure D-42. Questionnaire Results, ATOS Training Material: 55 of 56 respondents agreed the ATOS training material was effective.

MOE 2.6 Adequacy of ATOS component ruggedness

This MOE assesses the ruggedness of the RF tags, RCU, and HHR in an operational environment. The assessment of the ATOS component ruggedness was limited; however, TECEVAL data revealed the RF tags met the ruggedness requirements stipulated in the FRD. All RF tags performed nominally except for two inoperable RF tags (cause unknown). The assessment team did not observe any HHR failures due to handling by the warfighters; however, the assessment team observed the HHRs lock up on occasion and needed to be rebooted. The assessment team also observed two RCU failures. One failure was due to a faulty flash memory card and the second failure was due to a bad power supply. With the exception of the data transfer problems with the HHR and PP, ATOS performed nominally during the demonstration.

MOP 2.6.1 RF tag ruggedness

TECEVAL data revealed the RF tags met the ruggedness requirements stipulated in the FRD. The RF tags can operate between -20°F and +155°F and between 0% and 95% relative humidity (non-condensing). The RF tags functioned after a 15 kilovolt electrostatic discharge test and 4-foot drop onto concrete. The RF tags operated for 10 days at the Miesau and CAAA demonstrations where they were placed outdoors. RF tags were functional when they were shipped from CAAA to Norfolk Naval Station via commercial ground transportation.

MOP 2.6.2 HHR ruggedness

TECEVAL data revealed the HHR met the ruggedness requirements stipulated in the FRD. The assessment team observed no HHR failures during the demonstrations.

MOP 2.6.3 RCU ruggedness

TECEVAL data revealed that the RCU met the ruggedness requirements stipulated in the FRD. The assessment team observed two RCU failures during the demonstrations. The cause for the failures has not been determined.

MOE 2.7 Supportability of ATOS power requirements

This MOE assesses the power requirements for the RF tags, HHR, RCU, and PP. The assessment team observed no major issues with providing electrical power to support ATOS components during the demonstrations. Some CAAA users felt that providing electrical power to remote storage magazines or facilities could be a challenge. However, 24 VDC batteries or gas-powered electric generators could be used to support power needs at these remote sites.

MOP 2.7.1 Voltage for RF tag operation

No RF tags were replaced due to low battery power indication during the demonstrations.

MOP 2.7.2 Voltage for HHR operation

The HHR used two rechargeable batteries and docking stations to ensure power was maintained. The assessment team did not observe any power issues with the HHR.

MOP 2.7.3 Voltage for RCU operation

As long as the RCU was able to obtain 24 VDC, the RCU was able to operate without any problems.

MOP 2.7.4 Voltage for PP operation

The PP was hosted on a commercial laptop computer. As long as 120/220 VAC power was available, the PP continued to work.

MOP 2.7.5 Detection of type of electrical input power to RCU

During the demonstration, the 24 VDC power source came from a portable gas electric generator, High Mobility Multipurpose Wheeled Vehicle battery, or 120 VAC line power using a 24 VDC step down transformer.

MOP 2.7.6 Operator/SME assessment of RF tag power requirements

The Miesau munitions SME indicated the RF tag batteries should be replaceable instead of throwing away the RF tag. The warfighter wanted to see a visual indicator on the outside of the RF tag casing to display battery strength. Questionnaire responses indicated the RF tag power requirement was acceptable during the demonstration (**Figure D-43**). The unacceptable comments focused on the designing of the RF tags so that the operator can replace the batteries.

> *"Need to adopt a way to change out the batteries."*
>
> Warfighter

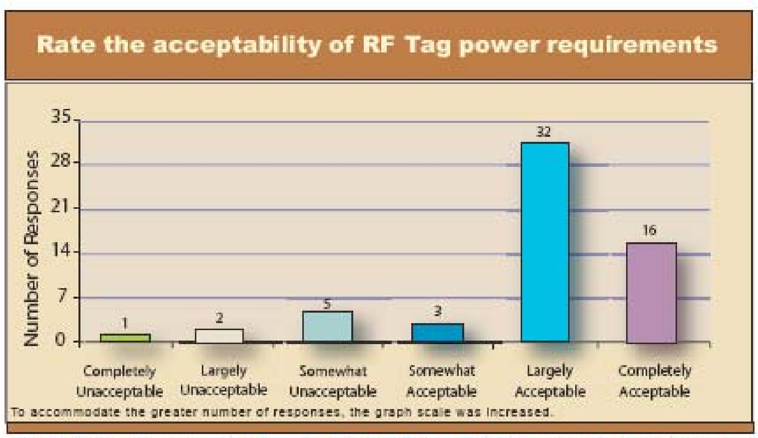

Figure D-43. Questionnaire Results, RF Tag Power Requirements: 51 of 59 respondents agreed that the RF tag power requirements were acceptable.

MOP 2.7.7 Operator/SME assessment of power requirements for HHR and RCU

The CAAA warfighter indicated power availability at remote storage locations would be a major concern. Many of these magazines will not have electrical power to support the HHR and RCU power requirements. Questionnaire responses indicated the HHR and RCU power requirements were acceptable during the demonstrations (**Figure D-44**). The unacceptable comment did not provide any information to improve the power requirement.

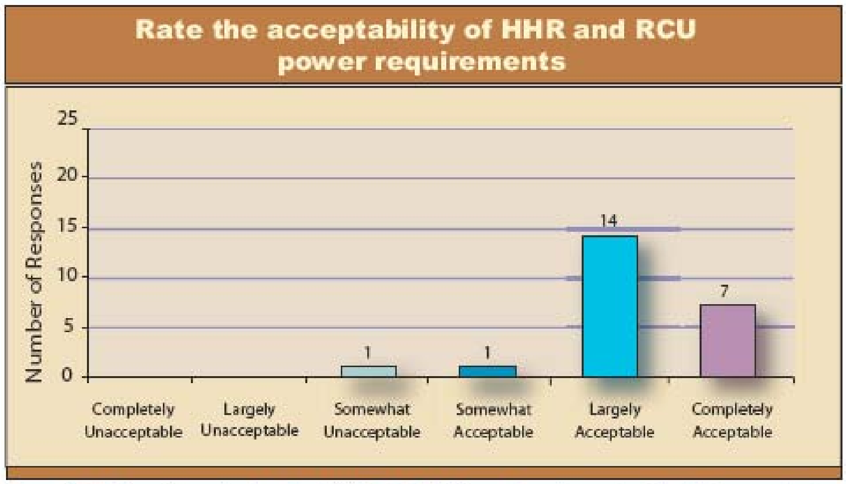

Figure D-44 Questionnaire Results, HHR and RCU Power Requirements: 22 of 23 respondents agreed the HHR and RCU power requirements were acceptable.

MOP 2.7.8 Operator/SME assessment of PP power requirements

The warfighters indicated the PP power requirements were straightforward and easy to accomplish as long as the PP was hosted in a facility that had 120/220 VAC electrical power (**Figure D-45**).

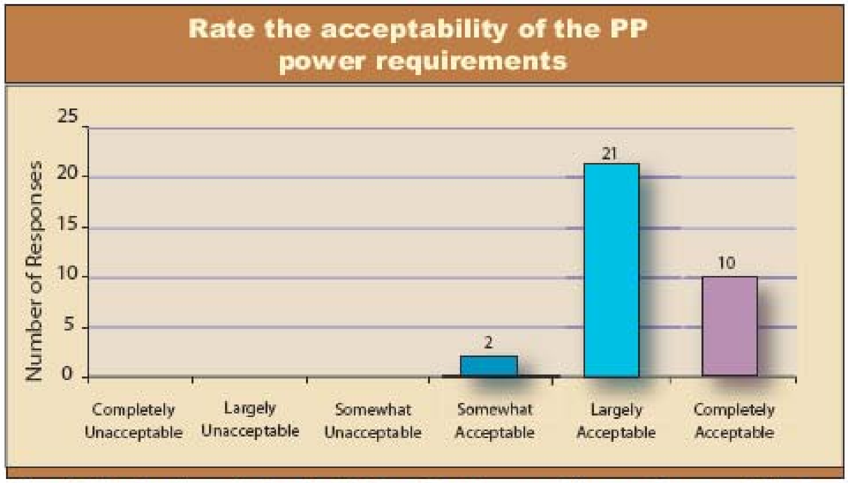

Figure D-45. Questionnaire Results, PP Power Requirements: *All respondents agreed that the PP power requirements were acceptable.*

MOE 2.8 Supportability of ATOS installation

This MOE assesses the installation of ATOS components. The installation at all the demonstration sites was quick and easy as long as there was a place to hang the RCU and RFEs and there was a 120/240 VAC power source for the RCU and RFEs.

MOP 2.8.1 Operator/SME assessment of RCU installation

The warfighters indicated the location and accessibility of the RCU were acceptable for the demonstrations as long as there was a place to hang the RCU and RFEs (**Figure D-46**). Tie wraps were used to install the RFEs and the RCUs were mounted on portable stands or a table. The unacceptable comment did not provide any information that would improve the RCU installation.

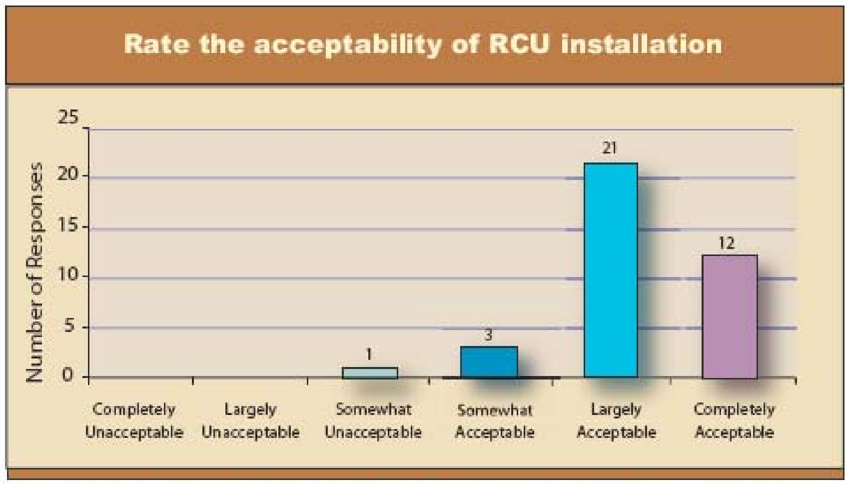

***Figure D-46. Questionnaire Results, RCU Installation:** 36 of 37 respondents agreed that the RCU installation was acceptable.*

MOP 2.8.2

The warfighter indicated the PP installation was straightforward since the software is hosted on a laptop. The questionnaire responses indicated the PP installation was acceptable during the demonstration (**Figure D-47**).

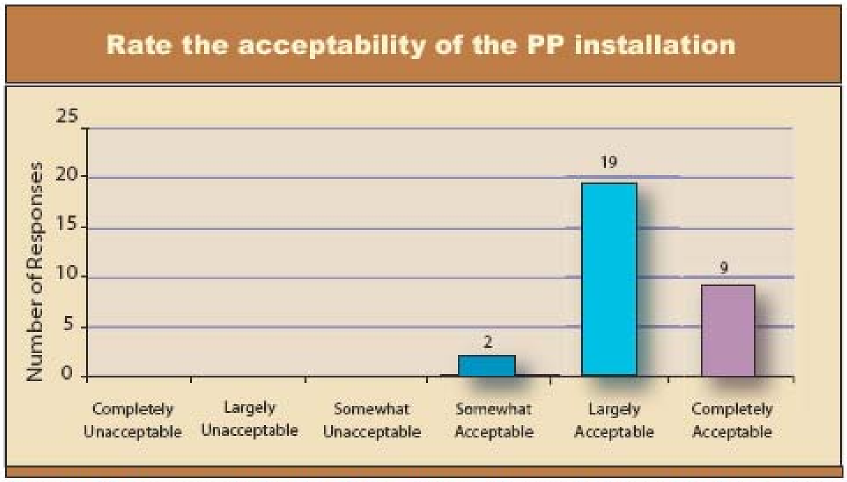

Figure D-47. Questionnaire Results, PP Installation: *All respondents agreed the PP installation was acceptable.*

Appendix E

Correlation of USEUCOM Functional Requirements Document to Measures of Performance Results

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As requested by USEUCOM, this appendix correlates FRD requirements, assessment results, and MOPs.

Requirements	Results	MOP
Data Tag		
1.1 **Attachment.** The RF tag will be inserted into a holder, which will be securely attached to the pallet or container.	During the demonstrations, both RF tags and tag holders remained attached to the munitions pallets. The warfighters indicated the RF tag attachment and attachment method used on the metal containers worked well.	2.1.1 2.1.3
1.1.1 Tag holder must securely attach to common ammunition packaging materials such as wood, laminates, steel, aluminum, fiberglass and plastics.	All 32 RF tags performed as designed. One RF tag holder came off a munitions pallet during the maritime demonstration. During the Miseau and Crane demonstrations, both RF tags and tag holders remained attached to the metal munitions pallets. The warfighters indicated the RF tag attachment and attachment method used on the metal containers worked well. Warfighters strongly recommended using wooden screws to secure the RF tag holders to the wooden box or pallets to prevent the RF tag holder from being pulled off during transport.	2.1.2 2.1.3
1.1.2 Tag holder must facilitate easy RF tag removal/replacement and can survive typical handling and transportation.	32 RF tags were shipped from CAAA to Norfolk Naval Station.	2.1.2 2.1.3
1.2 **Tag Memory.** The RF tag will have sufficient nonvolatile memory to store all tag data items	The warfighters indicated the RF tag data storage was adequate for storing asset and environmental data during the demonstration.	1.9.4
1.3 **Tag Sensors.** The demonstration RF tag will contain two sensors, temperature and relative humidity, with ports to support two additional sensors for future expansion. Up to 20 RF tags will contain a shock sensor to be used in parallel testing and evaluation at NAVSEA, Indian Head, MD for possible future RF tag application.	The temperature sensor was accurate within ± 1°F. The total of 400 RF tags were used during the demonstrations. 200 RF tags were used constantly to support all the demonstrations. Most of these RF tags were initialized in March 2004 (approximately 4700 hours operating time). The assessment team did not observe any failures in the temperature sensor and relative humidity sensors. The RH sensor was accurate within ± 10%. The RF tag can record and store for 45 days (1080 data points) of environmental data. The RF tag collected and recorded temperature and relative humidity data every 60 minutes. Confirm by reviewing the histogram data. During the demonstrations, the TM randomly selected the high and low user-selectable temperature and RH limits. Many of these settings were not operationally representative. Although the PP was able to display tripped flags, the assessment team did not know how many RF tags were used to demonstrate this capability. During the demonstrations, both RF tags and tag holders remained attached to the munitions pallets. The warfighters indicated the RF tag attachment and attachment method used on the metal containers worked well. However, warfighters were concerned about measuring the temperature and RH inside the individual munitions containers. Recommend RF tags be placed inside these containers rather than on the munitions pallets. When available, environmental sensors should be embedded in individual munitions.	1.2.2 1.2.3 1.2.4 1.2.5 1.2.8 1.2.9 1.2.10 1.2.11 1.2.12 1.2.13 1.2.14
1.4 **Shock Sensor.** The shock sensor will consist of non-resettable inertial switches with individually preset shock thresholds. There shall be two shock measures on each of the x-, y-, and z-axes. In the event of the tag experiencing a shock in excess of a sensor threshold, a data flag resident on the RF tag will be set to indicate the event.	Not assessed.	1.2.15 1.2.16 1.2.17 1.2.18 1.2.19 1.2.20
1.4.1 The failure rate for shock threshold excession flags being incorrectly set, or not set, shall be no greater than 5%.	Not assessed.	1.2.15 1.2.16 1.2.18 1.2.19 1.2.20

Requirements	Results	MOP
Data Tag		
1.5 Temperature Sensor and RF Tag Memory. The RF tag will tally temperature ranges experienced. Temperature tallies will be maintained in an array of memory bins correlating to 5 °F blocks. Memory capacity per memory bin shall be sufficient to hold all individual tallies.	The warfighter indicated the RF tag data storage was adequate during demonstrations.	1.9.4
1.5.1 Temperature sensors shall be accurate to ± 5 °F.	Temperature sensor was accurate within ± 1° F.	1.2.2
1.5.2 Total temperature tally data loss due to temperature sensor failure shall not exceed 5%.	The assessment team observed no failures in the temperature sensor.	1.2.3 1.2.23
1.6 **Relative Humidity Sensor and RF Tag Memory.** The RF tag will tally RH ranges experienced. RH tallies will be maintained in an array of memory bins correlating to 5% RH blocks. Memory capacity per memory bin shall be sufficient to hold all individual tallies.	The warfighter indicated the RF tag data storage was adequate during the demonstrations.	1.9.4
1.6.1 RH sensors shall be accurate to ± 5% RH.	RH sensor was accurate within ± 10%.	1.2.4
1.6.2 Total RH tally data loss due to RH sensor failure shall not exceed 5%.	The assessment team observed no failures in the RH sensor.	1.2.5 1.2.23
1.7 **Temperature Threshold Indicators.** The RF tag will have separate data elements to accommodate high and low temperature limits. A bit flag or indicator associated with exceeding a given high or low temperature limit will be set upon detection of that temperature.	During the demonstrations, the TM randomly selected the high and low user-selectable temperature limits. Many of these settings were not operationally representative. Although the PP was able to display tripped flags, the assessment team did not know how many RF tags were used to demonstrate this capability and the TM did not record the number of RF tags that had their temperature settings changed.	1.2.9 1.2.11 1.2.12 1.3.17
1.7.1 The failure rate for temperature bits on a single RF tag not being set upon the detection of their temperature shall be 5%.	The warfighter indicated changing the RF tag user-selectable temperature limits were easy to learn and operate the HHR. TECEVAL data showed 20 RF tags had their high and low temperature limits set. All 20 tags had their environment flags tripped at the appropriate limit settings. The assessment team observed no failure in the temperature sensor.	1.2.3 1.2.23
1.8 **RH Threshold Indicators.** The RF tag will have separate data elements to accommodate for high and low humidity limits. A bit flag or indicator associated with exceeding a given high or low humidity limit will be set upon detection of that relative humidity level.	During the demonstrations, the TM randomly selected the high and low user-selectable RH limits. Many of these settings were not operationally representative. Although the PP was able to display tripped flags, the assessment team did not know how many RF tags were used to demonstrate this capability. The warfighter indicated changing the tag user-selectable RH limits were easy to learn on the HHR.	1.2.10 1.2.13 1.2.14 1.3.17
1.8.1 The failure rate for RH bits on a single RF tag not being set upon the detection of their percentage shall not exceed 5%.	TECEVAL data showed 20 RF tags had their upper and lower RH limits set. All 20 tags had their environment flags tripped at the appropriate limit settings.	1.2.4 1.2.23
1.9 **Tag Transmission.** Once per hour, the RF tags will be initiated by an RCU. Each RF tag will transmit tag ID, limit flags, battery status, and any updates to the asset data and histogram since the previous transmission.	At the Miesau demonstration, the RCU detected 199 out of 200 RF tags (99.5%) in a 60' x 40' x 15' earth-covered magazine using three RFEs. RCU detected 169 out of 174 tags (97.1%) in a 70' x 200' ASP using eight RFEs. At the Crane demonstration, RCU detected 197 out of 200 tags (98.5%) in both the 100' x 50' x10' earth-covered magazine using 6 RFEs and 200' x 50' storage warehouse using 12 RFEs. At the Maritime demonstration, HHR detected 60 out of 60 RF tags (100%) in a 10' x 22' x 8' magazine on the USS Ponce (RCU was not installed) and 200 out of 200 RF tags in a 45' x 80' x 10 on the USS Harry S.Truman using 3 RFEs and RCU.	1.2.9 1.2.10 1.3.2
1.9.1 The tag will "wake up" every hour ± 10 minutes. This tag "wake up" will be controlled by a receiver counter on board the tag and will be set for hourly readings. The "wake up" interval will be accessible for change via an appropriate operator interface.	The TM RCU data logger was used at Miesau and CAAA demonstrations and system test to monitor the RCU software activity. The RCU data logger documented the start and stop times of the RCU. The results indicated that the RCU automatically interrogated the RF tags every 60 minutes. When the RCU detects a change in the RF tag asset information, the RCU sends a flag to the PP during the hourly interrogation.	1.3.2

Requirements	Results	MOP
Data Tag		
1.9.2 ATOS hardware configuration must allow for 100% coverage (communication between RF tag and reader) in a magazine.	The antenna coverage was exceptional at the demonstrations. At the Miesau and CAAA demonstrations, the RCU was able to detect at least 98.5% of 200 RF tags during the first interrogation cycle at both demonstrations and after the third interrogation cycle 100% of the RF tags were detected. At the maritime demonstration, RCU was able to detected 200 out of 200 RF tags on the USS Harry S.Truman.	1.10.1
1.9.3 The unobstructed read/write range between the RF tag and a HHR shall be at least 20 feet. The failure rate shall not exceed 5%.	The detection range between RF tags and the HHR is approximately 80 feet. The HHR will lock up if another HHR operates in close proximity (20 feet).	1.3.10
1.10 **Tag Receiver.** The RF tag will have a receiver that will allow data to be both written to, and read from, internal memory, and to respond to external commands from the HHR and RCU. The receiver will be available every 5 seconds.	Warfighters were able to read and write to the RF tags using the HHR. The RF tag was able to transfer the data to the HHR and RCU. However, warfighters stated the RF tag read-write processing speed needs improvement. The logistics and munitions SMEs indicated that the HHR would sometimes have trouble picking up the RF tag ID number. The munitions SMEs felt changing the tag user-selectable temperature was easy to learn and use with the HHR. The munitions SMEs felt changing the RF tag user-selectable RH limit was easy to learn and use with the HHR.	1.2.9 1.2.10 1.3.1 1.3.3 1.3.4 1.3.14 1.3.16 1.3.17 1.3.18 1.3.19
1.11 **Power Conservation.** The ability to increase the duration between commanded RF tag transmissions can serve as a method by which the battery power may be conserved.	Not assessed.	
1.12 **Battery Indicator.** The tag shall automatically switch over to a backup battery when the primary cell can no longer power the tag. When this occurs, a backup battery flag will be set which will provide the notification of a dead battery in need of attention.	20 RF tags switched over to their backup batteries and sent battery flags to the RCU when the main cells fell below 3.2 volts during TECEVAL. During the demonstrations, one RF tag transmitted a battery flag.	1.3.8 2.7.1
1.12.1 The total number of RF tags failing the requirement listed in paragraph 1.12 (Battery Indicator) during the system demonstration shall not exceed 5%.	No failures occurred during the TECEVAL and operational demonstrations.	1.3.8 2.7.1
1.13 **Tag ID.** The RF tags will have a unique numerical identifier on each individual tag delivered from the vendor. The ID number must be human-visible and barcode readable on the outside of the RF tag.	HHR was designed to display RF tag transaction records instead of displaying the RF tag ID. The warfighters needed to download the HHR transaction records to the PP to display the assigned RF tag ID. During the Miesau and CAAA demonstrations, the warfighters were able to identify 20 out of 20 RF tags using the HHR. During the maritime demonstration, the warfighters were able to properly identify 60 out of 60 RF tags (100%) by their assigned tag ID numbers. The warfighters were able to visually identify the 20 selected RF tags by their ID numbers at each demonstration. One warfighter stated, "[ID] numbers [were] readable and easily located." The HHR had some problems reading the tag barcode. Several warfighters stated, "[The] HHR had some difficulty reading tags consistently." The warfighters needed to place the HHR close to the RF tags to read the barcode.	1.3.5 1.3.6 1.3.7
1.14 **Tag Creation/Burning by HHR.** The operator will have the ability to create, or "burn," a new tag using data stored on a handheld reader.	The warfighters indicated the HHR was easy to use to create new RF tags. The warfighters were able to transfer RF tag data from a defective RF tag to the replacement RF tag. Occasionally, the HHR would have some difficulty transferring the data to the replacement RF tag. The warfighters stated the barcode labels were easy and quicker to input asset data to the RF tag.	1.13.1 1.13.2 1.13.3
1.15 **Tag Transmission.** The RF tag transmissions will be within HERO compliant radiated power parameters.	The RF tag transmitter power was at 240 mW, which met the HERO requirements.	1.3.12 1.3.13

Requirements	Results	MOP
Data Tag		
1.16 **Tag Frequency**. The RF tags must operate in frequencies approvable for CONUS and OCONUS host nations.	The RF tag transmitter frequency is 433.92 MHz. RF tags met the HERO requirements.	1.3.13
1.17 **Tag Ruggedness**. The tags must operate between -20°F and +155°F and between 0% and 95% relative humidity (non-condensing). The RF tags must also be operable after a 15 kilovolt electrostatic discharge test and 4-foot drop onto concrete. Additionally, the RF tags must be environmentally sealed so that exposure to outdoor elements does not cause damage to the tag. The tag should be able to survive typical handling and transportation. The 4-foot drop onto concrete (above) addresses shock requirements. Vibration requirements are based on the commercial vibration specification stipulated by the manufacturer.	The TECEVAL data revealed the RF tags met the ruggedness requirements stipulated in the FRD. The RF tags can operate between -20°F and +155°F and between 0% and 95% relative humidity (non-condensing). The RF tags can function after a 15 kilovolt electrostatic discharge test and 4-foot drop onto concrete. The RF tags operated for 10 days at Miesau and CAAA demonstration placed in the ASP. RF tags remained functional during the transfer from CAAA to the Norfolk Naval Station via commercial ground transportation.	2.6.1
HHR		
2.1 **HHR Data Transmissions and Reception**. The HHR will transmit instructions to the tag to change tag data such as quantity values or condition code, and will receive detailed asset data from the RF tag.	At the Miseau demonstration, the warfighters used the HHR find function to locate five tagged pallets to issue munitions items. All five tagged munitions pallets were located using the HHR. The warfighter was able to execute the roll call function using the HHR. No major problems were observed during the demonstrations. At CAAA demonstration, ATOS operator was able to conduct an inventory of an earth-covered magazine within 20 minutes using the roll call function. The warfighter felt this functionality would be a time saver in the field. During the maritime demonstration, the HHR was effective performing a speedy tally of 60 RF tags inside the USS Ponce 10'x 22'x 8' storage facility. The task was completed within 10 minutes. On the USS Harry S.Truman, Det 1 AFOTEC performed a roll call operation on 200 RF tags. The HHR was able to find 199 RF tags and one bad tag. The task was completed within 15 minutes.	1.2.9 1.2.10 1.3.1 1.3.2 1.3.3 1.3.4 1.3.16 1.3.17 1.3.18 1.3.19
2.2 **HHR Display and Keypad**. The HHR will have a display to show data received from the tag. It will have a keypad for manual entry of data into the tag memory, and a display screen for data from the tag. The keypad design will allow the user to enter data while wearing gloves. The use of a stylus, which is wired to the HHR, for keypad data manipulation is acceptable.	The warfighters stated the HHR keypad was easy to use to input asset information. The warfighters were able to use the stylus to input asset information. The stylus was especially useful when the warfighters were wearing bulky gloves in the Miesau demonstration. Some of the warfighters indicated the stylus was the quickest way of inputting changes to the asset data. Most of the warfighters thought the HHR display was user-friendly and easy to use. The warfighters indicated the HHR data entry was easy.	1.12.1 1.12.2 2.2.1 2.2.2
2.3 **New Tag and Barcode Creation**. The HHR will be able to create a new tag in a field environment. There will be three methods to create RF tag - (1) by use of the HHR keypad; (2) from container barcodes; (3) from the PP data that is stored on the HHR.	The warfighters stated the HHR was easy to use to create new RF tags. The warfighters were able to transfer RF tag data from a defective RF tag to the replacement RF tag. Occasionally, the HHR would have some difficulty transferring the data to the replacement RF tag. The warfighters felt using the barcode labels was the easiest and quickest way of inputting asset data to the RF tag.	1.13.1 1.13.2 1.13.3

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Requirements	Results	MOP
HHR		
2.4 HHR to PP Interface. The HHR will communicate with the PP by means of a direct connection (docking, removable media, or infrared) with the PP server.	At the Miesau demonstrations, four HHRs transferred receipted data to the PP during pallet receipt operations. The assessment team compared the count of the handwritten inventory list to the count of the PP inventory list. This comparison was accomplished at all demonstrations. At the CAAA demonstration, three HHRs transferred receipted data to the PP during pallet receipt operations. Note: The assessment team observed technical problems at the CAAA demonstration with the transfer of receipted data from the HHR to the PP. On the USS Ponce, three HHRs transferred receipted data to the PP during pallet receipt. On the USS Harry S.Truman, three out of four HHRs transferred receipted data to the PP during pallet receipt. Four HHRs were used to perform the pallet issue. The warfighters were able to update the pallet count and the assessment team verified the pallet count changes by visual inspection of the RF tags and PP. The warfighters stated the communication and data transfer interface with the HHR, RCU and PP needed some improvements to increase the reliability and accuracy.	1.4.1 1.4.3 1.4.7
2.5 HHR Removable Memory. The HHR will have removable data storage media such as flash memory cards.	Not assessed. The HHR did not have removable data storage media.	
2.6 HHR Multiple RF Tag Anti-collision. The HHR shall have an effective multiple tag signal anti-collision features.	The assessment team observed the HHR did not work if the RCU was interrogating RF tags at the same time. HHRs would also lock up if another HHR was in close proximity.	1.3.14
2.7 HHR Transactions. The HHR shall have the ability to perform receipt, issue, and transfer transactions as well as view and change asset data on an existing tag.	HHR was able to perform pallet receipt, pallet issue, transfer transaction records, and change asset data on the RF tags. At the Miesau demonstrations, four HHRs transferred receipted data to the PP during pallet receipt operation. The assessment team compared the count of the handwritten inventory list to the count of the PP inventory list. This comparison was accomplished at all demonstrations. At the CAAA demonstration, three HHRs transferred receipted data to the PP during pallet receipt operations. Note: The assessment team observed technical problems at the CAAA demonstration with the transfer of receipted data from the HHR to the PP. On the USS Ponce, three HHRs transferred receipted data to the PP during pallet receipt. On the USS Harry S. Truman, three out of four HHRs transferred receipted data to the PP during pallet receipt. Four HHRs were used to perform the pallet issue during the maritime demonstration. The warfighters were able to update the pallet count and the assessment team verified the pallet count changes by visual inspection of the RF tags and PP.	1.4.1
2.8 HHR Safeguards. The HHR shall have safeguards necessary to preserve data until successful communication with the PP.	Not assessed	
2.9 HHR HERO Compliance. The HHR transmissions will be within HERO compliant radiated power parameters.	The HHR transmitter power was 240 mW; that met the requirements for HERO.	1.3.12
2.10 HHR Future Design. Future design is for the HHR to operate in any military environment worldwide.	The TECEVAL data revealed the HHR met the ruggedness requirements stipulated in the FRD. The assessment team observed no HHR failure during the demonstrations.	2.6.2

Requirements	Results	MOP
RCU		
3.1 **Installation.** The RCU will be installed on ammunition storage and maintenance facilities and/or any other permanent, approved ammunition storage locations. [For ammunition magazines, it is possible that the RCU be mounted outside and the antenna cable run inside the magazine.] The RCU may be installed using accessory items, such as a tripod, to enable the RCU to be installed in field environments.	The warfighters indicated the location and accessibility of the RCU were acceptable as long as you have the infrastructure (conduit or wooden board) to hang the RCU and RFEs. Tie wraps were used to install the RFEs while the RCUs were mounted on a portable stand or table.	2.8.1
3.2 **Antenna Configuration.** Multiple antennas will be used for coverage of large magazines and field storage facilities if necessary.	At the Miesau and CAAA demonstrations, the RCU was able to detect at least 98.5% of 200 RF tags during the first interrogation cycle. During the second and third interrogation cycles, ATOS was able to detect 100% of the RF tags. At maritime demonstration, RCU was able to detected 200 out of 200 RF tags on the USS Harry S. Truman.	1.10.1
3.3 **RCU Communications.** The RCU will initiate hourly communications with the RF tags, collect tag ID, and any limit flags, and transmit this data to the PP via a WLAN. In the event that a WLAN connection is not available from the RCU to the PP, the RCU will have the capability to store 30 days of data from all tags within its range and transmit data when connectivity is restored. When a WLAN is not configured or not available, communication between the RCU and the PP is achieved via direct docking with the HHR.	RCU interrogated the RF tags every 60 minutes Demonstrations were one or two weeks long. The RCU storage memory capacity was 256 MB. The assessment team did not observe a data storage issue during the demonstrations, but maximum capacity was not assessed.	1.3.1 1.3.2 1.3.19
3.4 **Power Configuration.** The RCU shall operate from on VDC.	As long as the RCU was able to obtain 24 VDC power, the RCU was able to operate flawlessly. During the demonstration, the 24 VDC power source came from portable gas electric generator, High Mobility Multipurpose Wheeled Vehicle battery, or 120 VDC line power using a 24 VDC step down transformer. The CAAA logistics SME felt power availability at remote storage locations would be a major concern. Many of these magazines will not have the infrastructure to have electrical power to support the HHR and RCU power requirements.	2.7.3 2.7.5 2.7.7
3.5 **WLAN Operational Range.** WLANs will be used for data transmission between the RCU and the PP.	At the Miesau demonstration, a line of sight connection was established with the earth-covered magazine and PP. The distance between two locations was approximately less than an eighth of a mile. At the Crane demonstration, the WLAN was successfully connected to a repeater on top of a 75 foot water tower to establish a mile and half connection to the PP. At both demonstration sites, the WLAN was able to provide reliable connectivity from the RCU to the PP.	1.4.6
3.6 **RCU Multiple RF Tag Anti-collision.** The RCU shall have an effective multiple RF tag signal anti-collision feature.	The assessment team observed the HHR did not work if the RCU was interrogating RF tags at the same time.	1.3.14
3.7 **RCU HERO Compliance.** The RCU transmissions will be within HERO compliant radiated power parameters.	The RCU received radiated energy from the RF tags. The only RCU transmission came from the WLAN. The WLAN power radiated at 100mW Effective Isotropic Radiated Power, which met the HERO requirements.	1.4.4
3.8 **RCU Ruggedness.** The RCU will perform in a field environment. To successfully perform in the field the RCU must be sealed to commercial standard.	The TECEVAL data revealed the RCU met the ruggedness requirements stipulated in the FRD. The assessment team observed two RCU failures during the demonstrations. Cause for the failures has not been determined.	2.6.3

Requirements	Results	MOP
PP		
4.1 PP Data Dissemination. The PP will make asset data available to Service ammunition AIS. Environmental data will be available on the EDB at Indian Head, MD, or other central sites. Environmental data will be sent to the EDB by way of secure (128-bit encryption) internet connections.	Not assessed	
4.2 PP Data Visibility and Access: The PP will have a local data display capability. Users will be able to perform user-specified data queries and produce both hard copy and soft-copy reports based on these queries. Data access and manipulation will be possible only with system or database administrator access privileges	The warfighters indicated that using the PP display was easy. Operators were able to obtain the inventory and transaction information needed to manage the tagged munitions pallets. The warfighters stated data entry on the PP was easy using the user-friendly menus.	2.3.1 2.3.2
EDB		
5.1 Environmental Database Design. The EDB will receive sensor data from PPs worldwide via secure (128-bit encryption) Internet connections. Data will be accessed by end users via the same means.	Not assessed	
5.2 Lifetime Data Storage. The EDB will have the capability to store data for the entire lifecycle of each tagged munition.	Not assessed	
End -to-End System		
6.1 System Accuracy. The overall system will pass accurate data from the RF tags to the PP.	RF tags were successful in transferring asset and environment surveillance data to the PP.	1.1.1 1.1.2 1.2.2 1.2.4 1.3.5
6.1.1 Data from 95% of RF tags reporting to a reader will be detected by the PP within two consecutive roll calls (approximately 145 minutes based on hourly attempts) from the start of the test. Data from 99% of the RF tags in the test magazines will be detected by the PP within three consecutive roll calls (approximately 215 minutes based on hourly attempts) from the start of the test.	At the Miesau demonstration, the RCU was able to detect 199 out of 200 RF tags (99.5%) while the ASP RCU detected 194 RF tags (97.1%). At the Crane demonstration, the RCU was able to detect 197 out of 200 RF tags (98.5%) inside the earth-covered magazine and storage warehouse. At the maritime demonstration on the USS Harry S.Truman, the RCU was able to detect 200 out of 200 RF tag (100%) inside the ship magazine. All 200 RF tags were picked up during the second interrogation cycle.	1.11.1 1.11.2

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Appendix F

Correlation of Assessment Questionnaires to Environmental Surveillance, Munitions Management, and Measures of Performance

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The following table maps questionnaire statements to environmental surveillance, munition management and MOPs. Note that the Munitions QA task is not included in the table because it was not assessed during the demonstrations.

Questionnaire Statement	Environmental Surveillance	Munitions Management: Pallet Receipt	Inventory Maintenance	Pallet Movement	Pallet Issue	Pallet Transfer	MOP
Rate the acceptability of RF tag temperature sensor.	•						1.2.21
Rate the acceptability of RF tag relative humidity sensor.	•						1.2.22
Rate the reliability of the RF tag sensors	•						1.2.23
Rate the capability to charge the RF tag temperature limits from the reader.	•						1.3.16
Rate the capability to charge the RF tag relativity limit.	•						1.3.17
Rate the effectiveness of RF training.	•						2.5.1
Rate the effectiveness of HHR training.							2.5.2
Rate the effectiveness of RCU training.							2.5.3
Rate the effectiveness of PP training.							2.5.4
Rate the effectiveness of the ATOS training material.							2.5.5
Rate the acceptability of the RF tag location capability.		•	•	•	•	•	1.1.2
Rate the capability of the RF tags to execute an on-command report.		•	•	•	•	•	1.3.3
Rate the capability of the RF tags to execute an on-command memory reset.		•					1.3.4
Rate the acceptability for visually identifying the RF tag's unique identification number.		•	•	•	•	•	1.3.6
Rate the acceptability of the RF tag barcode readability.		•	•	•	•	•	1.3.7
Rate the acceptability of the RF tag's low battery power indication.		•	•	•	•	•	1.3.9
Rate the capability of the HHR or RCU to obtain the RF tag unique identification.		•	•	•			1.3.18
Rate the acceptability of transferring RF tag data to HHR and RCU.		•	•				1.3.19
Rate the effectiveness of data transfer from HHR to PP.		•	•				1.4.1
Rate the acceptability of transferring data from HHR or RCU to the PP.		•	•	•	•	•	1.4.7
Rate the acceptability of the ATOS system to support data transfer from the HHR to the PP.		•	•				1.4.1
Rate the acceptability of the ATOS system to support data transfer from several RF tags to the RCU and PP.		•	•				1.4.2
Rate the acceptability of the antenna coverage between the RCU and the RF tag.		•	•	•			1.10.2
Rate the usability of the HHR keypad.		•	•	•	•	•	1.12.1
Rate the usability of the HHR stylus.		•	•	•	•	•	1.12.2
Rate the capability of the HHR to create new RF tags.		•					1.13.1.
Rate the capability of the HHR to create replacement RF tags.		•	•	•	•	•	1.13.2
Rate the capability of the HHR to create barcodes.		•					1.13.3
Rate the acceptability of the RF tag attachments to the containers.		•					2.1.3
Rate the usability of the HHR display.		•	•	•	•	•	2.2.1
Rate the HHR data input usability.		•		•	•	•	2.2.2
Rate the usability of the HHR-RCU bridge.		•	•	•	•	•	2.2.3
Rate the usability of the HHR-PP bridge.		•	•	•	•	•	2.2.4
Rate the usability of the HHR-PP docking station.		•	•	•	•	•	2.2.5
Rate the usability of the PP display.		•	•	•	•		2.3.1
Rate the PP data input usability.		•	•	•	•		2.3.2
Rate the acceptability of configuring RF tags.		•	•	•	•	•	2.4.1
Rate the acceptability of configuring the HHR.		•	•	•	•	•	2.4.2
Rate the acceptability of configuring the RCU.		•	•	•	•	•	2.4.3
Rate the acceptability of configuring the PP.		•	•	•	•	•	2.4.4
Rate the acceptability of the RF tag power requirements.		•	•	•	•	•	2.7.6
Rate the acceptability of the HHR and RCU power requirements.		•	•	•	•	•	2.7.7
Rate the acceptability of PP power requirements.		•	•	•	•	•	2.7.8
Rate the acceptability of the RCU installation.		•	•	•			2.8.1
Rate the acceptability of the PP installation.		•	•	•	•	•	2.8.2
Rate the acceptability of the RF tag data storage memory capacity.		•	•	•	•	•	1.9.4
Rate the acceptability of the HHR and RCU data storage memory capacity.		•	•	•	•	•	1.9.5
Rate the acceptability of the PP data storage capacity.		•	•	•	•	•	1.9.6

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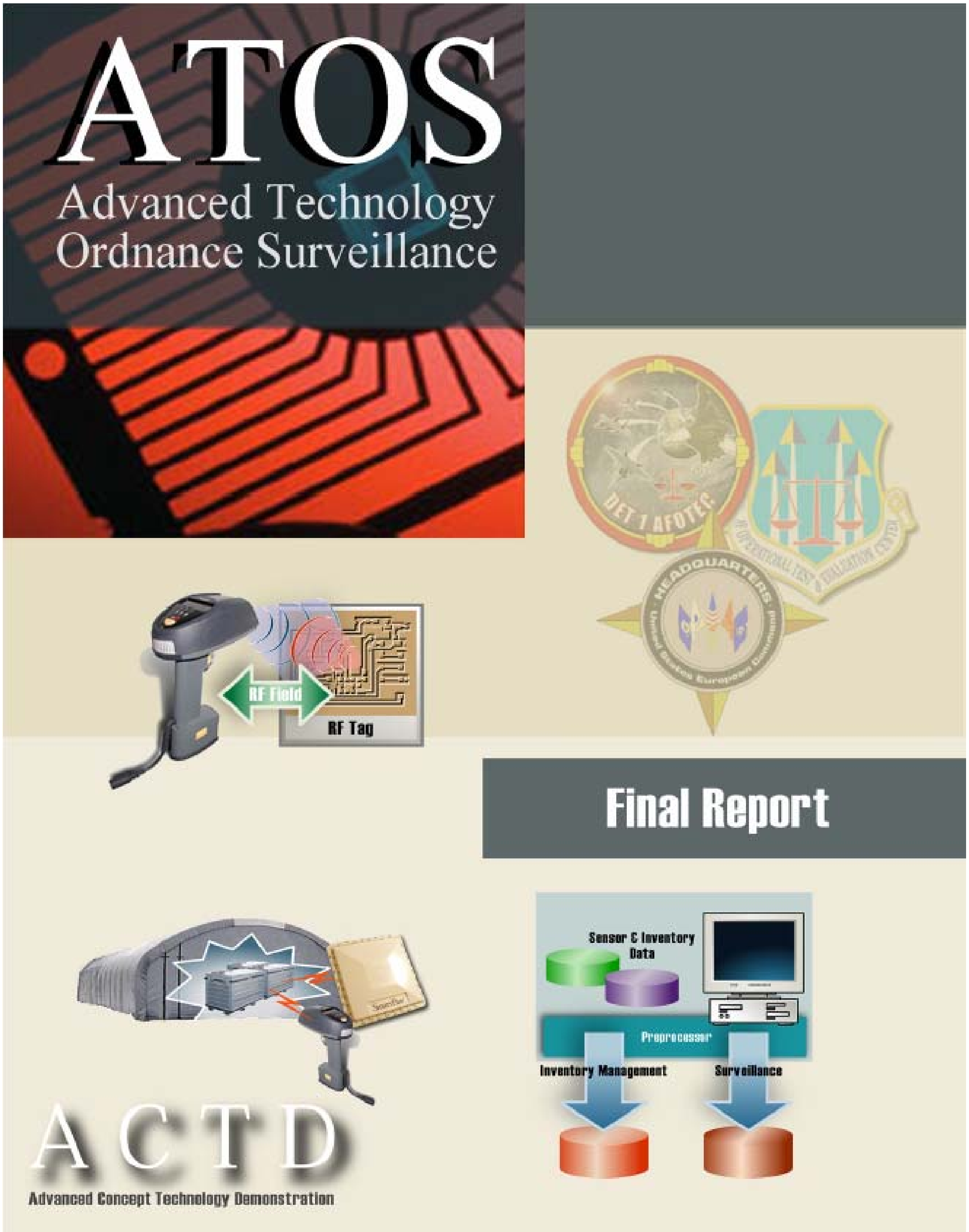
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RF Field
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