Use of Passive RFID Technology to Track Critical Patient Devices: Results of Wright-Patterson Medical Center Trial

CASE STUDY
October 2007

E Smith Consulting, LLC
"From Strategy to Success"

1 Background Information

1.1 Acknowledgements

The RFID Solutions Center would like to express our thanks to the following Department of Defense organizations and individuals that made this trial possible.

United States Air Force Medical Service
- ✓ Colonel Cary Collins (AFMOA/SGSL)
- ✓ Mr. Dave Baker (Chief, Chemical Eng AFMSA/SGSL)
- ✓ Mr. Steve Walker (AFMSA/SGRM)
- ✓ Kilby Gray (AFSSR/DMLSS)

Military Health Services
- ✓ Mr. Gary Duvall (DMLSS RFID Coordinator)

Wright-Patterson Medical Treatment Facility
- ✓ Commander Lt. Col. Parker
- ✓ Major Thomas L Moore
- ✓ Capt. Nathan Kellet
- ✓ SSgt. Mathew Kurian
- ✓ SSgt. William Fowler
- ✓ SSgt. Ryan Flynn
- ✓ Maj. Nielson
- ✓ MSgt. Patricia Rodgers

We would like to thank these individuals and acknowledge their significant efforts in implementing an emerging technology trial in a critical patient care setting.

1.2 Contract Information

Offering Department: U.S. Air Force Research Laboratory, Materials and Manufacturing Directorate (“AFRL/MLM”)

Recipient: Wright Brothers Institute

Vehicle: Memorandum of Understanding / Partnership Intermediary Agreement (“MOU” / “PIA”) FA8650-06-3-9000

Contract: Collaborative Purchase Order (“CPO”) FA8650-06-3-9021

Title: RFID Rapid Adoption Collaboration Initiative (“RRACI”)

The objective of the program is for the recipient to stimulate the rapid transition of radio frequency identification (RFID) technologies by developing an RFID solutions center. The RFID solutions center shall provide an effective way to collaborate with government end users, contractors, and defense industry suppliers. The solutions center shall provide education, training, and application of specific system design capabilities to transition RFID technologies to meet military needs. The RFID solutions center shall provide the capabilities and services that shall assist the government in streamlining both internal and external supply chain challenges to support the warfighter.

This effort was sponsored in whole or in part by the Air Force Research Laboratory, USAF, under Memorandum of Understanding/Partnership Intermediary Agreement No. FA8650-06-3-9000 with The Wright Brothers Institute, Inc. The U.S. Government is authorized to reproduce and distribute reprints for Government purposes notwithstanding any copyright notation thereon.

Table of Contents

Tables

Figures

2 EXECUTIVE SUMMARY

In October of 2007, the RFID Solutions Center (RSC) completed an RFID trial at Wright Patterson Medical Center to prove the feasibility of using UHF Passive RFID within a clinical setting to better track and manage assets.

Radio-frequency identification (RFID) is an automatic identification technology which combines inexpensive labels and radio infrastructure for tracking the identity and location of assets. Initiatives by large commercial entities like Wal*Mart and Procter and Gamble, as well as government entities like the department of defense, have been using RFID to streamline supply chain processes, enhance asset visibility, and improve readiness. Closed loop systems, such as healthcare facilities, are becoming increasingly interested in the use of this technology to improve service and reduce costs.

The Air Force Medical Service (AFMS) delivers medical service for more than 2.63 million eligible beneficiaries and runs 75 military treatment facilities, including 24 hospitals and medical centers. Using RFID to address common business problems can help hospitals absorb financial burdens and provided better quality of care. These common business problems include:

- ✓ Shrinkage of assets
- ✓ Underutilized assets
- ✓ Inefficient patient transport
- ✓ Inefficient use of diagnostic equipment and/or operating theaters
- ✓ Emergency room bottlenecks
- ✓ High-risk patient security

The trial, implemented with the help of Verisign and Elizabeth Smith Consulting, was limited in scope and did not include an operational analysis of productivity gains or other potential improvements in the management of hospital resources; instead mobile assets such as monitors and infusion pumps were affixed with RFID tags and tracked throughout the facility over a seven week period. Nine locations on three floors of the WPMC were examined for suitability for RFID system deployment. The trial was intended as a proof-of-concept for three hypotheses:

1. Could a passive RFID system accurately track medical equipment in and out of conglomeration points (storage areas)? The results of this comparison showed that the passive RFID system correctly located the medical equipment at an 85% accuracy rate.

2. Could a passive RFID system accurately track movement of medical devices throughout a medical facility? In investigating item-specific movement, data for one of the Prodigy II Patient Transport Monitors is detailed throughout the length of the trial.

3. Could a passive RFID system monitor traffic through passage zones of a hospital? Example results from this study included 22 round-trip events from the MSU to the ICU and back to the MSU with a mean average of about 40 minutes per trip, and several other trends demonstrating visibility of asset mobility and utilization were noted.

This high read rate accuracy indicates that the passive RFID system can be used to greatly assist users in locating equipment; however, the system should be used for general location of assets rather than relied upon for critical patient care needs. In addition, the study noted utilization on equipment (based on equipment which was stationary throughout the 7-week pilot versus moving throughout the pilot) indicated some equipment utilization was as low as 25%. As this only takes into account the equipment which never moved, and does not take into account when equipment was rarely used, actual utilization numbers are likely quite a bit lower. This indicates a significant opportunity exists in making needed equipment more available and reducing or better managing inventory which gets little use.

The trial successfully demonstrated that RFID can significantly enhance the ability of a medical facility to locate critical medical devices. The project team feels that RFID can accurately read equipment movement through the medical facility, eliminating much of the typical item search times, improving asset availability and utilization.

3 Introduction

This chapter defines the passive RFID technology tested in the trial. It also describes the trial hypothesis and concept, the project team, and the overall layout of this final report.

3.1 About Passive RFID

Radio-frequency identification (RFID) is an automatic identification method, relying on storing and remotely retrieving data using devices called RFID tags or transponders. Utilizing radio frequency waves, an RFID tag can be applied to or incorporated into a product for the purpose of location and identification. UHF Passive RFID can be read from several meters away and beyond the line of sight of the reader. Most RFID tags contain at least two parts. One is an integrated circuit for storing and processing information, modulating and demodulating a (RF) signal and can also be used for other specialized functions. The second is an antenna for receiving and transmitting the signal.

RFID technology is in increasing use in enterprise supply chain management, improving the efficiency of inventory tracking and management. The Department of Defense, along with major commercial companies such as Wal-Mart, is implementing systems to test the ability of this technology to improve asset visibility, product integrity and readiness throughout the supply chain.

The use of RFID in the DoD supply chain has the potential to provide real benefits in inventory management, asset visibility, and interoperability in an end-to-end integrated environment. RFID encapsulates the data accuracy advantages inherent in all types of automatic identification technology (AIT). Additionally, RFID is a totally non- intrusive methodology for data capture (requires no human intervention), is non- line of sight technology, and is a technology that possesses both read and write options within the same equipment item.

RFID addresses a key challenge that has been noted at every node within the DoD supply chain – lack of visibility of item data. As an integral aspect of the overarching suite of AIT capabilities, RFID will become a key technology enabler for the DoD logistics business transformation and will support long-term integration of the Unique Identification (UID) into the DoD end-to-end supply chain. RFID (both active and passive) is required by DoD to:

- ✓ Provide near-real time in-transit visibility for all classes of supplies and materiel
- ✓ Provide “in the box” content level detail for all classes of supplies and materiel
- ✓ Provide quality, non- intrusive identification and data collection that enables enhanced inventory management
- ✓ Provide enhanced item level visibility

Recent research has indicated that the potential for passive RFID applications in the medical environment is significant, and successful trials have been conducted in the pharmaceutical industry, clinical environment, and medical logistics area.

3.2 Hospital Benefits

About AFMS

The Air Force Medical Service (AFMS) delivers medical service for more than 2.63 million eligible beneficiaries. The AFMS runs 75 military treatment facilities, including 24 hospitals and medical centers. Currently, the quality and efficiency of patient care is hindered because of the effort required to locate critical medical equipment in these facilities. And, often, the scheduled maintenance and inventory information on these supplies is not accurate. Medical equipment is critical to treating injured active duty servicemen and therefore must be calibrated and maintained properly, and easily locatable when it is needed. Currently, these assets are typically managed through bar coding and manual inspections.

Many medical devices are bar coded for formal inventory but their locations are not readily identifiable when moved throughout the medical facility or when applied to a set kit or outfit. Once an item leaves a primary location, it is often not returned. The opportunity cost associated with the time spent looking for this equipment by both clinical staff and medical logistics is very high. Initiating passive RFID or replacing an existing bar code with passive RFID capability would potentially enable tracking of medical equipment within a medical treatment facility (MTF) using strategically located receivers. This could also facilitate reuse and recapture of the items that may reduce required inventory levels of expensive medical equipment.

Healthcare Industry Status

In today's managed care environment, health care organizations are searching for ways to increase revenue and reduce costs while providing better, more secure patient care for less reimbursement. To achieve profitability and succeed in a competitive marketplace, health care organizations are forced to improve productivity, operate more efficiently and maximize resources. Within the average size health care facility, fixing ***common business problems*** can help the institution absorb the financial burdens placed upon it by managed care and succeed in a highly competitive marketplace. These common business problems include:

- ✓ Shrinkage of assets
- ✓ Underutilized assets
- ✓ Inefficient patient transport
- ✓ Inefficient use of diagnostic equipment and/or operating theaters
- ✓ Emergency room bottlenecks
- ✓ High-risk patient security

Implementing a RFID within a facility can mitigate each of these business problems and result in a substantial return on investment. More importantly, the return on investment for RFID cascades for every additional problem addressed. The resulting return on investment grows even more rapidly as each new application is brought on-line.

The recent introduction of affordable RFID will have an immediate impact on health care facilities: reducing operational costs, increasing patient revenues and improving patient care. RFID addresses the following functions for assets and personnel:

- ✓ Locating in real time
- ✓ Tracking or producing an audit trail
- ✓ Increasing security via various alarming capabilities
- ✓ Checking inventory instantaneously

Health care facilities have several characteristics that create an excellent environment for a RFID because in general, these institutions tend to:

- ✓ Operate 24 hours per day – 7 days per week
- ✓ Consist of large facilities with multiple egress points
- ✓ Contain expensive, mobile equipment which is in constant demand
- ✓ Rely on a manually intensive system to transport patients throughout the facility

Investment

The implementation of a RFID contains two cost components: a fixed cost consisting of the antennas and readers and a variable cost consisting of the "tags" that identify an asset or an individual.

RFID's substantial return on investment is due to its flexible nature. That is, once the fixed cost components are installed, they may be used for a variety of applications. Each new application addresses a business problem, which in turn increases the return on investment.

Potential Benefits Defined

Shrinkage: Our first business problem is to reduce the yearly shrinkage of mobile assets throughout the facility due to misplacement and pilferage. Of particularly interest to most healthcare environments is the tracking of mobile assets. Reducing shrinkage by 25 – 50% can have a significant impact to return on investment.

Under-utilization: Health care institutions can greatly benefit from increasing their patient-day device utilization. If a health care facility can maximize asset utilization, they can then begin to drive down costs. Implementing RFID as an asset tracking tool will help hospitals maximize equipment utilization. As an added benefit, real-time asset tracking will reduce a facility's need to purchase additional units and rent back up devices. The return on investment is noted either by reducing equipment rentals or by reducing the number of devices within the hospital due to improved utilization.

Inefficient patient transport: Another common business problem is the inefficiency of the dispatch and transport process for moving patients. An inefficient system requires too many transporters to cover the institution's transport needs. With increased efficiency, the transport staff may be re-deployed.

Inefficient usage of diagnostic / OR equipment: In this situation, an expensive piece of diagnostic equipment or even a surgical procedure is kept idle, waiting for a patient to arrive. The manually-intensive transport process does not always result in patients being delivered to the appropriate locations in a timely manner. Moreover, delays that occur when physically finding each patient may increase the inefficiency.

ER Bottlenecks: For a facility with substantial emergency activity, the ER may be closed to new arrivals once per week due to over capacity caused by improper ER utilization. When this occurs, patients are re-routed to other hospitals until the situation is brought under control and the ER can support the patient volume.

High-risk patient security: How does a hospital ensure the safety of its most vulnerable patients? This is an important question for which, there was no real answer until the introduction of the RFID. RFID can ensure the safe monitoring and tracking of all high-risk patients, such as newborns, Alzheimer's patients and the mentally handicapped. How does an institution measure the value of providing this safe, effective service for these patients? Most would say that it is incalculable because the stakes are so high.

Benefits Summary

As a result, the RFID yields the following results:

- ✓ Substantial return on investment via decreased costs and increased revenue
- ✓ Increased staff efficiency
- ✓ Improvement in the quality of care
- ✓ An expandable system that may be enhanced to solve additional business problems without incurring much cost

A RFID will allow health care organizations to improve productivity, operate more efficiently and maximize resources and become more competitive in today's managed care environment. More importantly, an RFID system can ensure the safety of its most vulnerable patients.

3.3 Project Team

This project was conducted by a team of passive RFID and Air Force medical logistics professionals and supported by the Air Force Surgeon General's Office and the Wright-Patterson Medical Treatment Facility (MTF) leadership. The project team was comprised of the Air Force Surgeon's General's Office, the Wright Brother's Institute, Wright-Patterson Medical Treatment Facility, Alien Technology, VeriSign, and E. Smith Consulting, LLC. The team roles are described below.

Air Force Surgeon's General Office (AFSG)

The AFSG sponsored this trial from a program office perspective and brought significant project oversight and support. This office provided support in trial site selection and coordination as well as development of the project metrics and issue resolution. Expertise brought by AFSG included:

- ✓ Healthcare Operational Environment
- ✓ Tri-service hospital environment
- ✓ Asset management issues around patient movement items
- ✓ Existing applications and business processes
- ✓ DOD medical supply chain

Wright-Patterson Medical Treatment Facility

As the trial site, significant support was provided by the Wright-Patterson Medical Center (WPMC), from the commander to the medical logistics personnel to clinical staff. While every attempt was made to make the trial as unobtrusive as possible, the WPMC staff assisted in ensuring that project design objectives were met and the trial system implementation was possible.

Wright Brothers Institute

The Wright Brothers Institute was the recipient of the grant and is the prime contractor for this contract.

Alien Technology Corporation

Alien Technology Corporation (ATC) was the sole subrecipient of the grant and provided overall program management as well as significant support through the RFID Solution Center (RSC) for training, integration facility support, and RFID solution engineering support. Alien Technology provides UHF Radio Frequency Identification (RFID) products and services to customers in retail, consumer goods, manufacturing, defense, transportation and logistics, pharmaceuticals and other industries. The RFID Solutions Center, a division of ATC, is the most advanced facility devoted entirely to the application of RFID technology. Open to enterprises, government agencies and their partners, the Center comprises 23,000 square feet of educational, R&D and real-world implementation resources designed to enable the global RFID community to tap the potential of RFID technology.

VeriSign

VeriSign served as the systems integrator on the project and provided project management services. With deep systems expertise on RFID data management, the VeriSign team integrated the RFID data with new and existing systems. VeriSign is a recognized leader in passive RFID implementations across multiple industry verticals including healthcare management.

E Smith Consulting, LLC

E. Smith Consulting, LLC provided overall project quality control and coordination on the project including project oversight and coordination with the Air Force Surgeon General's office and the RFID Solution Center. ESC provided subject matter expertise in Air Force Medical Logistics, process development, metrics collection, and analysis support.

3.4 Report Layout

The remainder of this report describes the trial design, findings, conclusions, and recommendations. The next section provides the trial methodology, timeframe, site selection process, and selection of the medical devices for testing. The physical design, information systems design, and physical layout of the readers within the Wright-Patterson Medical Treatment Facility are provided. The following section describes the findings with regard to the three proof-of-concept areas, while the final section provides an overall conclusion and recommendations for a permanent roll-out of a passive RFID system within the facility.

4 Methodology

This chapter describes the trial project and its phases, deliverables, and timelines. The selection of the trial site and medical devices are described, as well as the physical layout of the readers within the facility, the information system approach, and installation lessons learned that will be helpful in future projects of this nature.

4.1 Trial Information

This trial project, conducted with the full support of the Air Force Surgeon General's office, tested the feasibility of using passive RFID to track critical medical devices in an actual Air Force clinical setting. This trial, planned and conducted from September of 2006 through September of 2007, tested the ability of passive RFID technology to track medical devices in the Wright-Patterson Medical Treatment Facility (MTF) located in Dayton, Ohio, using commercially-available standards-based RFID components and software over an 7-week period.

The primary goal of the trial was to assess the effectiveness of and mitigate risks from using passive RFID technology to track medical equipment within a designated hospital facility, and to also determine whether this type of technology merited consideration for implementation in the larger Air Force medical community. The trial was limited in scope and did not include an operational analysis of productivity gains or other potential improvements in the management of hospital resources; these benefits could be more adequately measured with a larger medical device sample size now that the proof-of-concept for the system is completed.

Each medical device included in the trial had an RFID tag affixed which responded to a radio signal sent via an RFID reader. As each tag passed through a given reader's radio frequency field, that tags' RF signal would be read and processed by the reader. Consequently the tags' location-information would then be identified, and this information would be stored into a database. The trial testing gauged the system's ability to accurately find tagged equipment in both conglomeration points (storage areas) and passage zones (surgical unit to intensive care unit, surgical unit to medical equipment maintenance center) within the hospital. The trial was intended as a proof-of-concept for testing whether passive RFID could run safely and effectively within a critical care environment, testing three hypotheses.

- ✓ Could a passive RFID system accurately track medical equipment in and out of conglomeration points (storage areas)?
- ✓ Could a passive RFID system accurately track movement of medical devices throughout a medical facility?
- ✓ Could a passive RFID system monitor traffic through passage zones of a hospital?

This proof-of-concept trial tested the ability of the trial system to run without MTF staff support and without impacting patient care. In other words, the trial system ran "invisibly" within the facility during the trial.

The overall methodology is shown in Figure 1 with associated timeframes, tasks, deliverables, and major Air Force check points. Initial testing performed in the MERC uncovered the need for further testing of medical equipment due to the appearance of RF interference. Further Interference testing was performed off-site at the RFID Solutions Center with the full participation of MERC personnel. Upon determining from interference testing how to offset interference *at this particular site* through attenuation (reducing the power-output level of the RFID equipment), and upon the installation of additional power outlets for the RFID equipment in some locations, the test trial was *then* performed at WPMC. The live trial ran for seven weeks in the Wright-Patterson MTF. Data was collected on location, for approximately ninety pieces of medical equipment that were tracked. ***note* Please read section 7.7, Appendix G (Interference) for important <u>additional</u> information about interference and reader attenuation, and for important notes about <u>interference testing requirements</u>***

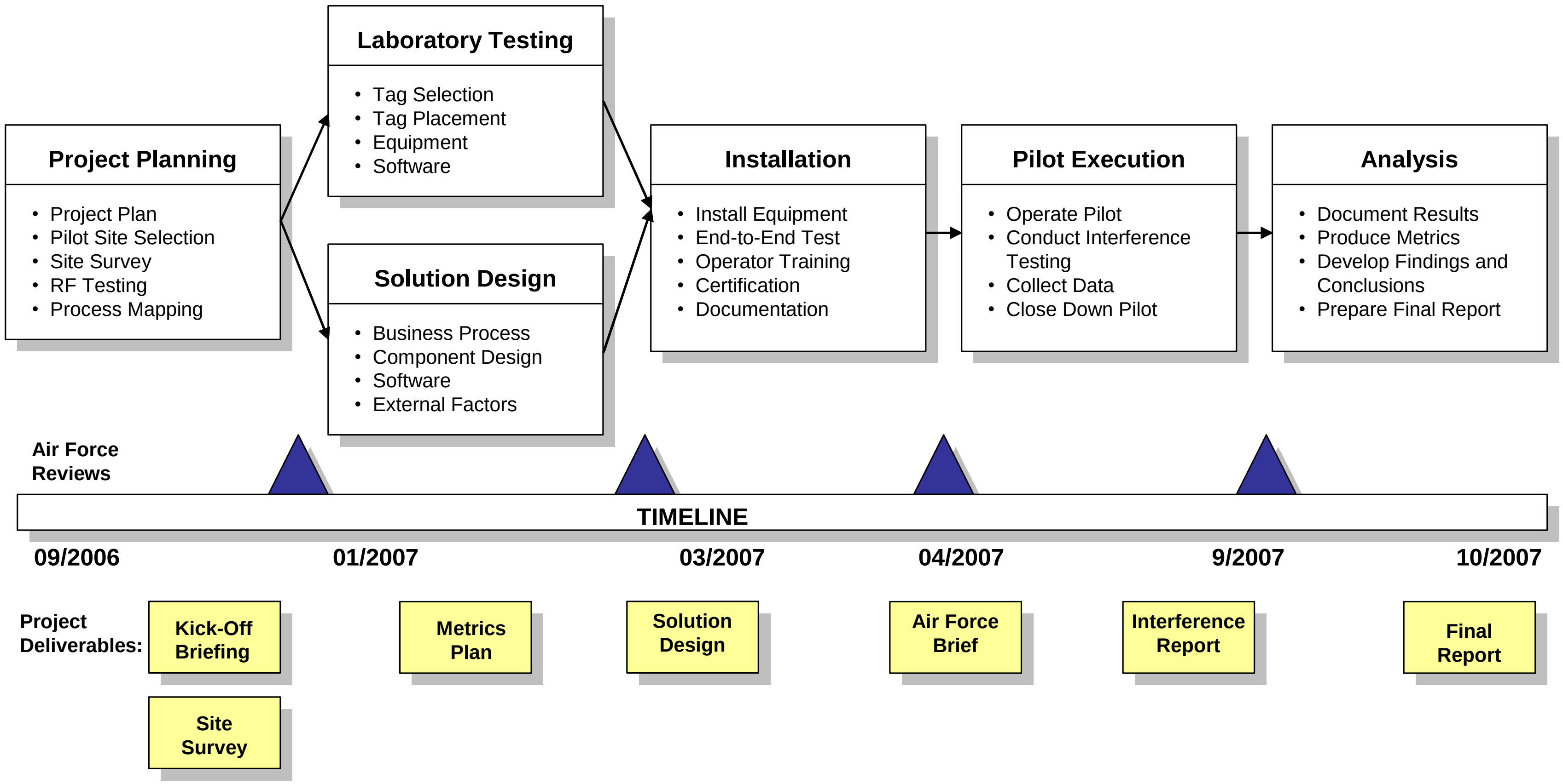

Figure 1: Diagram - Trial Methodology

4.2 Site Selection

Upon approval of the trial concept by the Air Force Surgeon General's Office, Wright Patterson Medical Center, and the RFID Solutions Center, the trial site selected was Wright-Patterson Medical Treatment Facility, located at 88MDG 4881 Sugar Maple Drive, WPAFB, Dayton, OH 45433.

- ✓ WPMC is a JCAHO-accredited 301 bed, multi-specialty facility and is representative of the type and complexity of DOD medical treatment facilities in the United States.
- ✓ There is significant volume of medical devices used throughout the facility that provided
- ✓ Proximity to the RFID Solutions Center to assist with trial design, testing, and troubleshooting
- ✓ The facility utilizes a Medical Equipment Repair Center (MERC) that maintains medical equipment for the entire facility.

Recommendation of WPMC was made by the Air Force Surgeon General's Office and approval was granted through the Commander, WPMC. A surgical ward and the MERC were identified as the two primary test areas where significant amounts of medical equipment were used, stored, retrieved, and maintained and significant throughput of equipment occurred on a weekly basis.

4.3 Medical Equipment Selection

The trial tested the movement of twenty-five types of medical equipment in the surgical unit and the MERC as shown in Table 1. The medical equipment was selected based on the urgent need for patient care as well as equipment needed for patient transport. Ninety pieces of equipment were tagged for the purposes of the trial.

Table 1: Tagged Assets

Item Description
Abbott Lifecare 4100 PCA Plus II Infuser
Alaris Infusion Pump
Bladder Scan
Critikon Vital Signs Monitor
Everest Jennings Vista Wheelchair
Hausted Mobile Bed (Steris)
Hill-Rom Advanced Series Bed
Hill-Rom Advanta Mobile Bed
Hill-Rom Total Care Bed
Invacare Tracer LX Wheelchair
Invacare Wheelchair Tracer EX2 (Narrow)
Invicare Tracer IV Wheelchair (wide)
Laerdal Suction Unit (Aspirator)
MAC 5000
Portable Defibrillator (3)
Prodigy II Patient Transport Monitor
Scale Tronix Patient Scale
SelectFlo Ext. Feeding Pump
Staxi Wheelchair
Stryker Critical Care Bed (w/scale)
Stryker Emergency Renaissance Bed
Stryker Mobile Bed
Tuffy Wheelchair
Venaflow System 30A

WelchAllyn Vital Signs Monitor

4.4 Site Survey

A site survey was conducted in November of 2006 to examine candidate sites within the MTF as potential areas for the installation of RFID equipment. The site survey was performed in two phases, a *Layout Analysis* that mapped the physical location(s) where the RFID system would be implemented and a *Radio Frequency (RF) Spectrum Mapping* to identify facility sources of radio frequency (RF) interference at the designated physical locations.

The *Layout Analysis* identified issues concerning the proposed location(s) that may effect RFID equipment, including but not limited to concerns such as power and network drops, obstructions, and metal infrastructure in the surrounding area.

The *RF Spectrum Mapping* involved recording detailed measurements of possible interfering signals within the vicinity of the proposed RFID location(s). Any interfering signals were measured and recorded for further analysis. The source of these signals was then determined to assist in mitigating their possible effects. The RFID systems investigated for use at the four sites utilized the ISM frequency band (902-928 MHz). A 24-hour scan was used to assess potential anomalies in the ambient RF environment.

The RF spectrum mapping revealed an RFID-friendly RF environment at most locations, but with one notable exception. The vestibule area showed a strong signal at 900.5 MHz which could possibly interfere with RFID operations in that area. While this area did not end up being part of this trial, implementation of wireless throughout the facility may be impacted by this signal. ***Please read section 7.7, Appendix G (Interference) for important <u>additional</u> information about interference, and for additional notes about <u>interference testing requirements</u> associated with patient-care devices***

4.5 Physical Design

Nine locations on three floors of the WPMC were examined for suitability for RFID system deployment. Two floors and six zones that included the MERC and a third-floor surgical ward were selected as suitable for the live trial due to the following features:

- ✓ Analysis of these sites revealed no major layout issues that would impact placement of RFID assets
- ✓ Most locations provided for a common “choke point” that would reduce the number of reader/antenna combinations to be deployed.
- ✓ Within these two locations, multiple read points were identified as a result of the on-site inspection, initial system design and site survey. These read points are broken down into two classifications:
- ✓ Conglomeration Points: Areas where the assets being tracked tend to pool (i.e. storage closets)
- ✓ Passage Zones or Portals: Areas where the assets being tracked tend to pass through and are intended to assist in the identification of directionality.

The two diagrams on the following page show the layout of these floors and indicate the read points where the passive RFID readers were placed (indicated by the purple dots). In initial discussions concerning power and network requirements, it was decided to have each RFID reader/antenna combination operate as a separate stand-alone system to eliminate the need for network connections and the resulting wiring issues. Power would be accessed via facility power cabling in the immediate proximity to each reader, typically above the acoustical ceiling tiles. Pictures of installed systems can be found in the appendix.

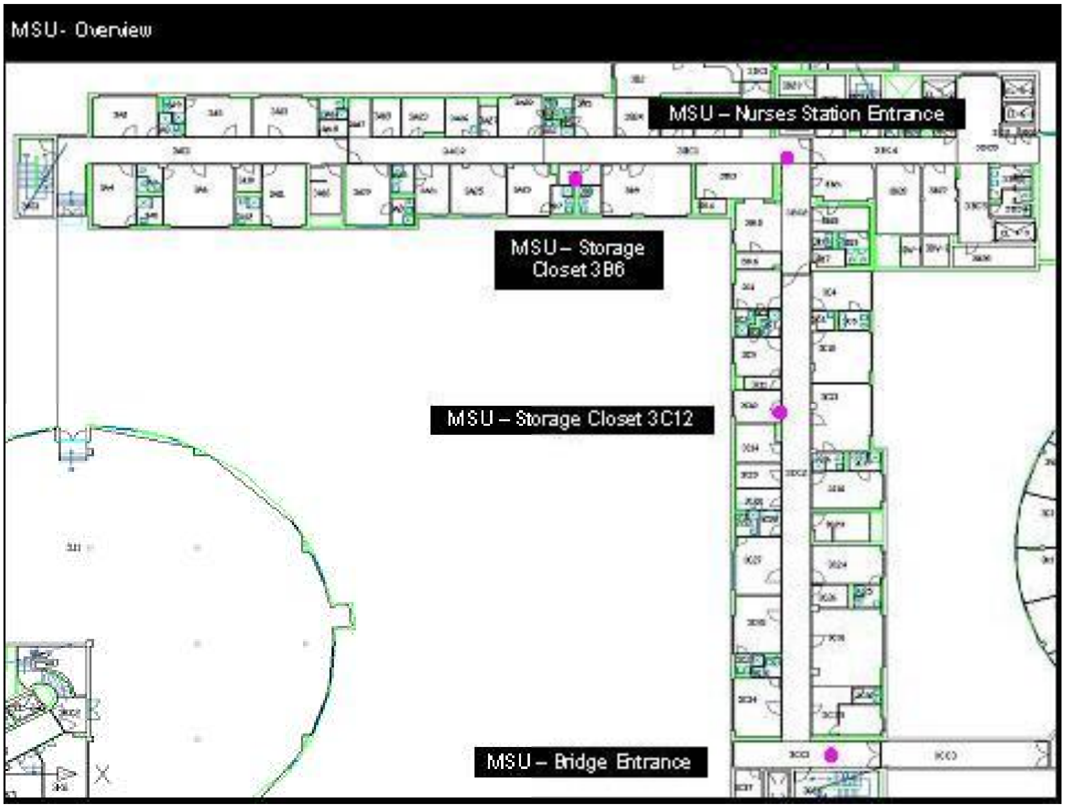

Figure 2: Diagram - MSU Coverage

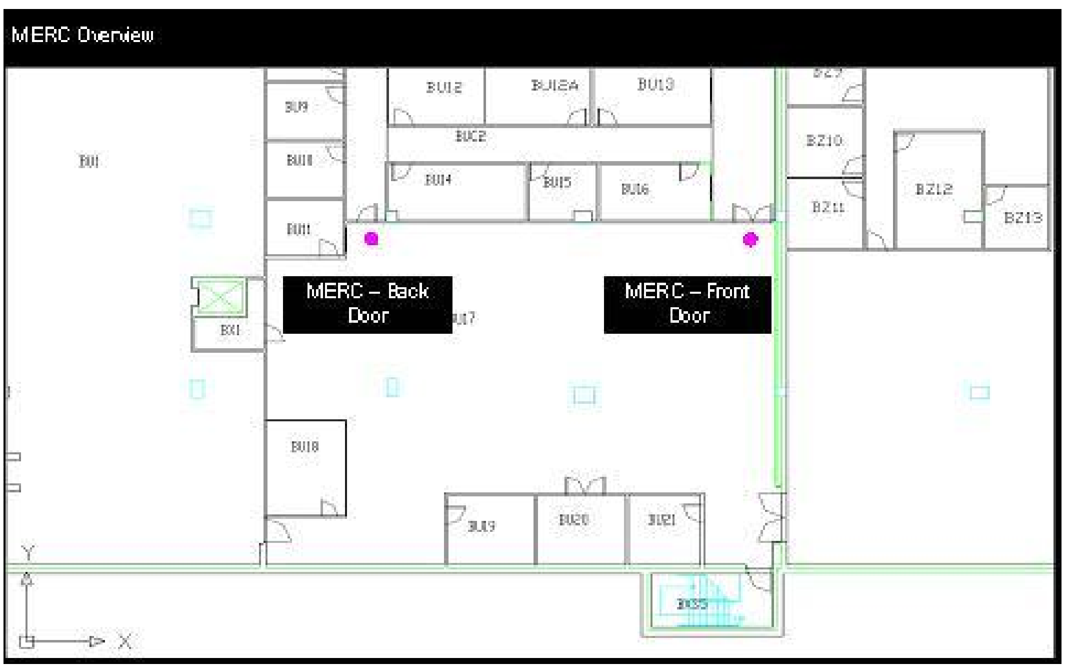

Figure 3: Diagram - MERC Coverage

4.6 System Components

RFID equipment for the trial included:

- ✓ Alien Technology ALR-9800 Readers
- ✓ Alien Technology ALR-9610-BC Antennas
- ✓ SmallPC SC240-CD2-1GM Servers
- ✓ Alien Technology ALN-9540 Squiggle Tags.

Stand-alone servers acted as data recording devices for the tags being read throughout the zones. RFID "middleware" was installed on each of the servers to facilitate the data recording. The trial system included custom software for ease of data collection and cost. Due to the limited nature of the trial, there was no interaction between the system itself and the Defense Medical Logistics Support System (DMLSS).

4.7 Hospital Coverage

The Trial implemented six read locations on the MSU ward and the MERC. Capturing reads in these locations allowed analysis of the effectiveness of a passive RFID system on a scaled basis where equipment is moving within the ward as well as to and from the MERC. Three coverage zones were established using these six read locations as follows:

- ✓ MSU Storage Rooms (3C12 and 3B6): These two coverage zones, located on the Multi-Specialty Unit ward (MSU), were set up to monitor departmental inventory patterns for clinical care devices by tracking 'in and out' activity.
- ✓ Maintenance Equipment Repair Center (MERC):This zone was set up to monitor time spent on individual item repair by tracking ' in and out' activity
- ✓ Passage Area Zones between the MSU and the ICU (Nurses Station and Bridge): These zones were set up to monitor the traffic-patterns of clinical-care devices between two adjacent departments.

The solution design also allowed for determining directionality of the equipment movement. Physical location of equipment was established through a set of team-generated physical inventory logs that were developed and maintained for the trial.

4.8 Lessons Learned

During installation of the readers into the hospital, various challenges were encountered and on-site fixes developed. Three of these observations are worth noting for purposes of wireless installations into these types of facilities.

- ✓ During the initial installation of the antenna arrays, a custom antenna mount utilizing the original acoustic tile with added support was utilized. This final design was accepted for the duration of the trial but a long-term solution should be devised for roll-out.
- ✓ Due to the large amount of wiring above the ceiling tiles, it is critical to coordinate wiring plans with on-site facilities management as well as other contractors that may be performing similar work in affected areas. A pre-work walkthrough with on-site officials is mandatory.
- ✓ Any equipment installed should have adequate battery backup allowing for uptime between power-outage and the generators coming on-line. Installation of battery backups should be carefully planned for space, mechanical and source power outlet considerations and all fire and safety regulations should be closely observed.

5 Results

This chapter provides the results against the three proof-of-concept areas for the trial described in the first chapter. First, the results of tracking equipment in and out of conglomeration points are provided, including the ‘item location’ success rate for the three zones of coverage. Second, the results of tracking a single device throughout the facility are provided. Third, the ability of the system to identify traffic-flow patterns between departments is described. In addition, potential benefits around improving utilization are discussed.

5.1 Zonal Coverage

The first proof-of-concept requirement of the trial was to determine whether the passive RFID system could track medical equipment in and out of storage and other conglomeration points (such as the MERC). The passive RFID trial compared medical equipment tag location data at the conglomeration points (storage areas on the MSU, ICU, and the MERC) against physical location of the equipment. The results of this comparison showed that the passive RFID system correctly located the medical equipment at an 85% accuracy rate over the seven weeks of the live trial. There were a total of 113 entrance and exit movement events within the performance-measuring zones over the course of the trial. The results for identifying entrance and exit event identified correct varied between the three conglomeration points:

- ✓ MSU Storage Room 3B6: 100%
- ✓ MSU Storage Room 3C12: 81%
- ✓ MERC: 89%

This high read rate accuracy indicates that the passive RFID system can be used to greatly assist users in locating equipment; however, the system should be used for general location of assets rather than relied upon for critical patient care needs. The variations in read rates by conglomeration points are indicative of this type of system and can be improved through repositioning of antennas (reducing user "blockage" of tag signals with the readers) and technology improvements.

5.2 Internal Asset Tracking

The second proof-of-concept element of the trial was to determine whether the passive RFID system could accurately read equipment movement through the medical facility. To demonstrate this proof-of-concept, a comparison of trial data received at non-conglomeration points (pass-through read points) against physical location of the equipment was documented for one select tag located on a patient transport monitor for the entire seven week trial.

The passive RFID system was able to identify the exact location of one of the Prodigy II Patient Transport Monitors throughout the entire length of the trial. Each time the item entered or exited one of the storage rooms, it was logged. The reads from the corresponding pass-through zones where the tag passed en route to its location destination were also logged. Examples of the specific nature of this tracking are below:

- ✓ The item spent most of its time in the MSU, bouncing back and forth between storage rooms 3B6, 3C12 and those patient rooms in the MSU.
- ✓ One note of interest is that on August 8th, it was seen leaving the MSU by way of the Nurses Station, and subsequently it appeared (approximately 2 minutes later) downstairs in the MERC. It remained in the MERC for exactly 16 days, after which it was then tracked leaving the MERC until it was picked up (3 minutes later) in the MSU. Once back in the MSU, it resumed its activity of transferring around between storage rooms and pass-through areas.
- ✓ There did not appear to be a designated home base for this item specific to either storage room (3B6 or 3C12), as it appeared to simply enter into whichever room was closer to the room where it was last used.
- ✓ Throughout the trial, the amount of time this item spent in either storage room varied from only a few minutes, to a couple of days; however the average stay seemed to be a few hours.
- ✓ There was a single instance of the item moving directly from one storage room to the other without making a stop along the way (This was recorded on August 1st).
- ✓ The table in the Trial Data section provides a color-coded event table of the results of tracking this individual asset (tag 181) throughout the facility.

5.3 Traffic Patterns

The third proof-of-concept requirement for the trial was to test the ability of the passive RFID system to monitor and identify traffic patterns of medical equipment through the hospital. The purpose of this requirement is to assist facilities in positioning critical medical equipment in a manner that maximizes their utilization and reduces unnecessary inventory.

The trial looked at the ability of the system to monitor traffic-flow patterns between the two respective departments and to accurately gather information on item-utilization patterns associated with times of day and days of the week. The trial tested this concept by creating two individual zones (the Nurses' Station and the Bridge) to work in conjunction to form a collective dividing line between the MSU and the ICU Departments. This information was analyzed over the course of one week of the trial. A select set of anecdotal findings of this successful tracking component are provided below:

- ✓ Many medical devices were transported between the MSU and the ICU. Most of these items' point of origin was the MSU where they were predominantly located at the end of the week
- ✓ There were a total of 15 individual *devices* that were transferred between the two departments (at least once) over the course of the week
- ✓ From those 15 items, there were a *total* of 50 traceable "departmental item-transfer" events that occurred between the two departments
- ✓ 70 % of those "departmental item-transfer" events occurred through the Nurses Station Zone, while the other 30% occurred through the Bridge Zone

- ✓ There were 22 round-trip events from the MSU to the ICU and back to the MSU with a mean average of about 40 minutes per trip
- ✓ There was 1 round-trip event from the ICU to the MSU and back to the ICU that took approximately 6 hours and 10 minutes
- ✓ The busiest days (where the largest number of *individual* items transferred between departments) were Friday August 24th and Wednesday August 29th
- ✓ Items consistently travel back and forth between departments during all hours of the day and most hours of the night

This anecdotal information demonstrates that the system can accurately track traffic patterns of medical equipment through a medical facility. By increasing the number of items tagged and adding zones to cover a larger amount of the facility, analysis of traffic and utilization patterns of equipment will result in the ability to improve access to maintained, needed patient medical devices.

5.4 Utilization

For the purposes of this case study, the team measured utilization as whether a tagged device was stationary throughout the life of the 7-week study. This is summarized in the following table to give characteristic information:

Eqiupment	Value	Number Tagged	Number Stationary	Utilization Rate
Abbott Life Care Infusion Pump	$ 2,499	8	6	25%
Alaris Infusion Pump	$ 2,265	22	1	95%
SelectFlo External Feeding Pump	$ 819	6	3	50%
VenaFlow System	Unkown	12	1	92%

Table 2: Utilization Summary

Note that this is only describing the equipment which was stationary throughout the 7-week study: equipment which was used only once throughout the pilot would be shown in the above table as 100% utilized when its true utilization might be much lower. The table above shows that there is significant opportunity to improve utilization by better managing assets.

6 Conclusions

The trial successfully demonstrated that Radio Frequency Identification (RFID) can significantly enhance the ability of a medical facility to locate critical medical devices. RFID is an automatic identification technology which combines inexpensive labels and radio infrastructure to streamline supply chain processes, enhance asset visibility, and improve readiness. This pilot was developed in concert with Air Force engineers and site personnel. The pilot was designed to test whether passive RFID could prove to be a viable, cost effective solution for the tracking of storage, movement, and traffic patterns of mobile assets used throughout the Air Force Medical Service network of treatment facilities. The project team feels that RFID can accurately read equipment movement through the medical facility, eliminating much of the typical item search times, improving asset availability and utilization, and recommends that a full implementation of a passive RFID system is the proper next step. The team feels that RFID is a cost effective solution due in part to the extremely reduced, up 90%, equipment search time and the insight into asset utilization, discovering some assets at only 25% utilization. Reducing the search time and increasing asset utilization translates to the right equipment in the right place at the right time, helping to enhance patient safety and decrease wait time. The team feels that this solution will be easy to implement and maintain, while providing greater visibility. The project team would like to thank everyone for their participation. This trial would not have been possible without their involvement.

6.1 Feasibility

The trial successfully demonstrated that a relatively inexpensive passive RFID system can significantly enhance the ability of a medical facility to locate critical medical devices. Anecdotal information from the medical facility indicates that the medical logisticians spend a significant amount of time (up to weeks) looking for medical devices that need to be maintained - armed only with their ability to inquire of hospital personnel and to search various storage areas within the facility. Clinicians, requiring calibrated and properly maintained medical equipment, rely on these logisticians and, when there are systemic inefficiencies, unnecessary inventory increases are the remedy to ensuring a high quality patient care environment.

6.2 Summary of Results

The nature of this trial was limited, and utilized a limited number of coverage zones that were relatively distant from each other. The trial was intended to provide proof-of-concept for three key concepts, and anecdotal information on excess inventory. It was determined through this trial that the passive RFID system can:

- ✓ Accurately track medical equipment in and out of storage and other conglomeration points with a minimum 85% accuracy rate
- ✓ Accurately read equipment movement through the medical facility, eliminating up to 90% of typical item search times
- ✓ Monitor and identify traffic patterns of medical equipment through the hospital.
- ✓ Improve visibility to equipment utilization allowing opportunities to better manage assets, improving care while reducing costs.

As the system configuration and technology improves, the 85% accuracy rate will increase. However, due to the nature of urgent patient care, it is recommended that passive RFID system *not* be used as the primary means to find critical patient-care devices in real time, but instead be used to improve the accuracy and speed of collecting information about assets.

While full inventory impacts were not able to be accurately projected through the limited nature of the trial, the test found that 9% of tagged trial equipment never moved from its original storage point. This is indicative that there is excess inventory that could be better utilized through improved asset tracking capabilities within the facility.

6.3 RFID Interference **Important**

Interference *was* detected between the RFID equipment that was used and two patient-care devices. This interference was ultimately mitigated *at this particular site* by attenuating (significantly reducing the power-output level) of the RFID equipment. ***Please read section 7.7, Appendix G (Interference) for important additional information about interference and RFID-reader attenuation, and for important notes about interference testing requirements***

6.4 Next Steps

Full implementation of a passive RFID system that 1) covers the major conglomeration points and passage zones of the hospital and 2) tags all major medical devices can be done inexpensively and will yield significant improvements in the availability of maintained critical patient movement items and medical devices. Integration of passive RFID asset tracking data into the Defense Medical Logistics Support System (DMLSS) would enable a significant improvement in the ability of the medical logisticians to identify equipment that is needed for maintenance with their location.

7 APPENDICES

7.1 Appendix A: Medical Equipment Used for Testing

Table 3: Tagged Assets Detail

USAFMS RFID Trial ECN Register					
Location	Item Description	ECN	TAG ID	Dept Tag	Unit Cost
MERC	Portable Defib	033450	09		$8,000
MERC	Portable Defib	033448	0D		$8,000
MERC	Portable Defib	033449	0F		$8,000
MERC	Portable Defib	033451	0E		$8,000
MERC	Laerdal Suction Unit (Aspirator	031953	B5		$700
MERC	Laerdal Suction Unit (Aspirator	031977	D7		$700
MERC	Laerdal Suction Unit (Aspirator	031943	B9		$700
MERC	Laerdal Suction Unit (Aspirator	028760	A7		$700
3C12	Alaris Infusion Pump	27486	100	MSU	$2,265
3C12	Prodigy II Patient Transport Monitor	032035	51	NONE	$3,484
3C12	Prodigy II Patient Transport Monitor	032033	181	MSU	$3,484
3C12	SelectFlo Ext. Feeding Pump	032624	27	MSU	$819
3C12	Alaris Infusion Pump	027514	F6	MSU	$2,265
3C12	Abbott Lifecare 4100 PCA Plus II Infuser	015014	144	NONE	$2,499
3C12	Abbott Lifecare 4100 PCA Plus II Infuser	015035	F1	MSU	$2,499
3C12	Abbott Lifecare 4100 PCA Plus II Infuser	015020	49	MSU	$2,499
3C12	Abbott Lifecare 4100 PCA Plus II Infuser	15019	102	MSU	$2,499
3C12	Abbott Lifecare 4100 PCA Plus II Infuser	015043	111	MSU	$2,499
3C12	Abbott Lifecare 4100 PCA Plus II Infuser	015017	C8	MSU	$2,499
3C12	Abbott Lifecare 4100 PCA Plus II Infuser	015010	14B	MSU	$2,499
3C12	SelectFlo Ext. Feeding Pump	032890	D2	NONE	$819
3C12	SelectFlo Ext. Feeding Pump	032626	74	MSU	$819
3C12	SelectFlo Ext. Feeding Pump	032630	137	MSU	$819
3C12	SelectFlo Ext. Feeding Pump	032625	46	MSU	$819
3C12	SelectFlo Ext. Feeding Pump	032623	F3	MSU	$819
3C12	Alaris Infusion Pump	27521	1001	MSU	$2,265
3C12	Abbott Lifecare 4100 PCA Plus II Infuser	15033	14C	ICU	$2,499
3C12	Alaris Infusion Pump	27557	16C	ER	$2,265
3C12	Alaris Infusion Pump	27489	DD	MSU	$2,265
3C12	Alaris Infusion Pump	27491	97	MSU	$2,265
3C12	Alaris Infusion Pump	027526	98	MSU	$2,265
3C12	Venaflow System 30A	025972	9B	MSU	LOANER CONTRACT
3C12	Venaflow System 30A	025969	66	MIU	LOANER CONTRACT
3C12	Venaflow System 30A	025976	3B	MSU	LOANER CONTRACT
3C12	Venaflow System 30A	025980	BD	MIU	LOANER CONTRACT
3C12	Venaflow System 30A	025981	BA	MSU	LOANER CONTRACT
3C12	Venaflow System 30A	025966	15D	MSU	LOANER CONTRACT
3C12	Venaflow System 30A	025979	43	MSU	LOANER CONTRACT
3C12	Venaflow System 30A	025974	34	MSU	LOANER CONTRACT
3C12	Venaflow System 30A	025977	C3	MSU	LOANER CONTRACT
3C12	Venaflow System 30A	025970	1E	MSU	LOANER CONTRACT
3C12	Alaris Infusion Pump	027516	77	MSU	$2,265
3B6	Prodigy II Patient Transport Monitor	032037	65	MSU	$3,484
3B6	Prodigy II Patient Transport Monitor	032038	151	MSU	$3,484
3B6	Bladder Scan	032308	B4	MSU	$11,406
3C4	Alaris Infusion Pump	27517	155	MSU	$2,265
3C11	MAC 5000	032096	2F	MSU	$9,412
3C12	WelchAllyn Vital Signs Monitor	034507	2B	NONE	$7,599
Hallway	Prodigy II Patient Transport Monitor	032036	FB	MSU	$3,484
3A6	Hill-Rom Advance Series Bed	026138	10D	MSU	$7,924
3A6	Hill-Rom Advanta Mobile Bed	030173	6D	MSU	$7,452
3A6	Hausted Mobile Bed (Steris)	24791	13B	MSU	$2,841
3A6	Stryker Mobile Bed	23954	40	MSU	$3,118
3A6	Hill-Rom Total Care Bed	31837	9C	MSU	$29,108
3A6	Invicare Tracer IV Wheelchair (wide)	NONE	135	ER	UNKNOWN

SVC ELE	Tuffy Wheelchair	NONE	C1	NONE	UNKNOWN
Hallway	Hill-Rom Advance Series Bed	026149	22	MSU	$7,924
MERC	WelchAllyn Vital Signs Monitor	035200	4E	NONE	$7,599
MERC	WelchAllyn Vital Signs Monitor	035198	4B	NONE	$7,599
MERC	WelchAllyn Vital Signs Monitor	035199	8C	NONE	$7,599
MERC	Staxi Wheelchair	NONE	D8	NONE	UNKNOWN
MERC	Critikon Vital Signs Monitor	027429	EB	NONE	UNKNOWN
Hallway	Prodigy II Patient Transport Monitor	032039	DO	MSU	$3,484
3B6	Alaris Infusion Pump	027488	114	MSU	$2,265
3B6	Alaris Infusion Pump	027487	55	MSU	$2,265
3A6	Hill-Rom Advance Series Bed	026147	1A	MSU	$7,924
3C12	Prodigy II Patient Transport Monitor	32040	1C8	NONE	$3,484
Hallway	Hill-Rom Advance Series Bed	26137	116	MSU	$7,924
3C13	Alaris Infusion Pump	27520	C5	MSU	$2,265
3C13	Alaris Infusion Pump	27515	5C	MSU	$2,265
3C18	Alaris Infusion Pump	027518	6B	MSU	$2,265
3C18	Alaris Infusion Pump	27484	F0	MSU	$2,265
3A13	Alaris Infusion Pump	27482	109	MSU	$2,265
3C12	Venaflow System 30A	025978	121	NONE	LOANER CONTRACT
3C12	Venaflow System 30A	025975	105	NONE	LOANER CONTRACT
3C12	Alaris Infusion Pump	027497	E9	ER	$2,265
3C12	Scale Tronix Patient Scale	035173	38	NONE	$1,705
3A6	Invacare Wheelchair Tracer EX2 (Narrow)	NONE	41	NONE	UNKNOWN
3A6	Everest Jennings Vista Wheelchair	NONE	68	NONE	UNKNOWN
3A6	Invacare Tracer LX Wheelchair	NONE	15C	NONE	UNKNOWN
3A6	Hill-Rom Advance Series Bed	027695	12F	MSU	$7,924
MERC	Stryker Critical Care Bed (w/scale)	20973	C7	ICU	$8,906
MERC	Stryker Emergency Renaissance Bed	20984	AD	NONE	$4,068
MERC	Stryker Emergency Renaissance Bed	20987	08	NONE	$4,068
MERC	Alaris Infusion Pump	030189	EF	APU	$2,265
MERC	Alaris Infusion Pump	030195	DA	APU	$2,265
MERC	Hill-Rom Advanced Series Bed	26235	86	SNU	$7,160
UNK	Alaris Infusion Pump	34437	D4	SIU	$2,265
UNK	Alaris Infusion Pump	34436	3C	SIU	$2,265
UNK	Alaris Infusion Pump	31366	13F	SIU	$2,265
UNK	Stryker Critical Care Bed (w/scale)	20982	A6	ICU	$8,906
					$52,357.00

7.2 Appendix B: Reference Documentation

The following documentation was developed or referenced to complete this activity:

ID	Document Name	Description
1	Design_RFID-WPMC_0.1.pdf	Solution Design Document
2	Interference_RFID-WPMC_0.3.pdf	Interference Report
3	DS_ALR-9800.pdf	ALR-9800 Spec Sheet (RFID Reader)
4	DS_ALN-9540.pdf	ALN-9540 Spec Sheet (RFID Tag)
5	DS_ALR-961x.pdf	ALR-9611 Specification Sheet (RFID Antenna)

7.3 Appendix C: Pictures

MERC Front Door

Figure 4: Picture - MERC Front 1

Figure 5: Picture - MERC Front 2

Figure 6: Picture - MERC Front 3

MERC Back Door

Figure 7: Picture - MERC Back 1

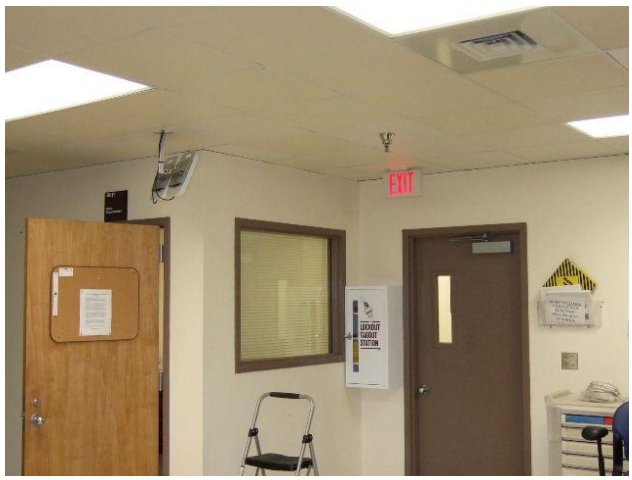

Figure 8: Picture - MERC Back 2

Figure 9: Picture - MERC Back 3

3C12 Storage

Figure 10: Picture - 3C12 Storage 1

Figure 11: Picture - 3C12 Storage 2

Figure 12: Picture - 3C12 Storage 3

3B6 Storage

Figure 13: Picture - 3B6 Storage 1

Figure 14: Picture - 3B6 Storage 2

Figure 15: Picture - 3B6 Storage 3

MSU Bridge

Figure 16: Picture - MSU Bridge 1

Figure 17: Picture - MSU Bridge 2

7.4 Appendix D: System Design

The solution design also allowed for determining directionality of the equipment movement. At any given read check-point, neighboring RFID interrogators were positioned to allow for directionality to be determined on tagged assets. Physical location of equipment was established through a set of team-generated physical inventory logs that were developed and maintained for the trial.

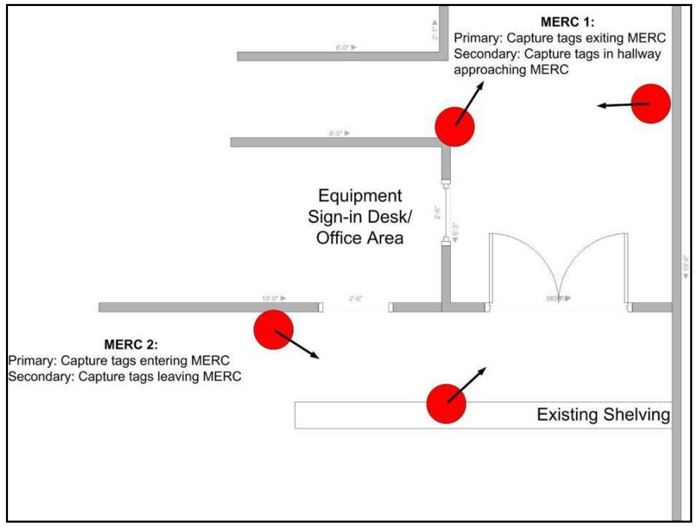

Figure 18: Diagram - MERC Font

Read Location #1 – MERC Front Door

The red dots indicate the reader placement and the black arrows indicate RF direction. The function of the antennas at Read Location #1 was to provide capture of tagged equipment moving into and out of the MERC via the front entrance. By tying into the reads of tags leaving and entering the MSU ward, movement of medical equipment between the two departments was extrapolated from the trial data.

Read Location #2 – MERC Back Door

The function of the antennas at Read Location #2 was to provide capture of tagged equipment moving into and out of the MERC via the back entrance. Although this was not a primary portal to the MERC, it was determined there was a relatively high probability of having medical equipment move through the back entrance. By tying into the reads of tags leaving and entering the MSU ward, we can extrapolate movement of medical equipment between the two departments. Exhibit II-6 shows the second read location for the MERC.

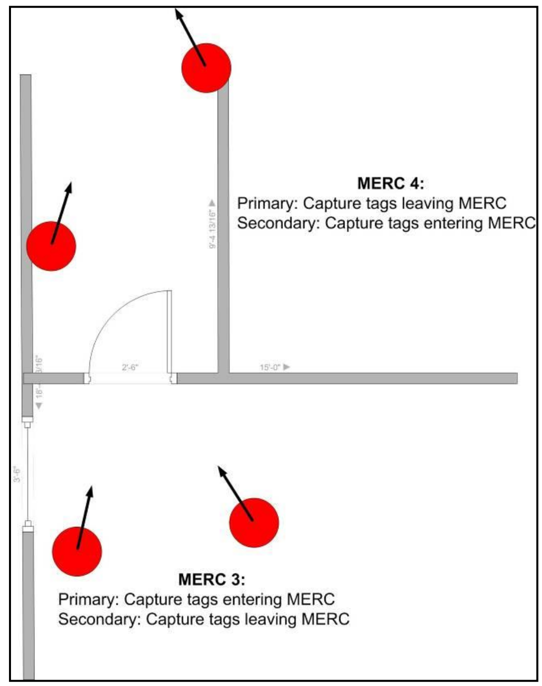

Figure 19: Diagram - MERC Back

Read Location #3 – MSU Nurses' Station

The function of the antennas at Read Location #3 was to provide capture of tagged equipment moving into and out of the MSU via the entrance next to the Nurse's station. It also allowed for detection of movement within the MSU by adding a third read station located down the hallway headed to the MSU bridge entrance. By tying into the reads of tags leaving and entering the MERC, we can extrapolate movement of medical equipment between the two departments.

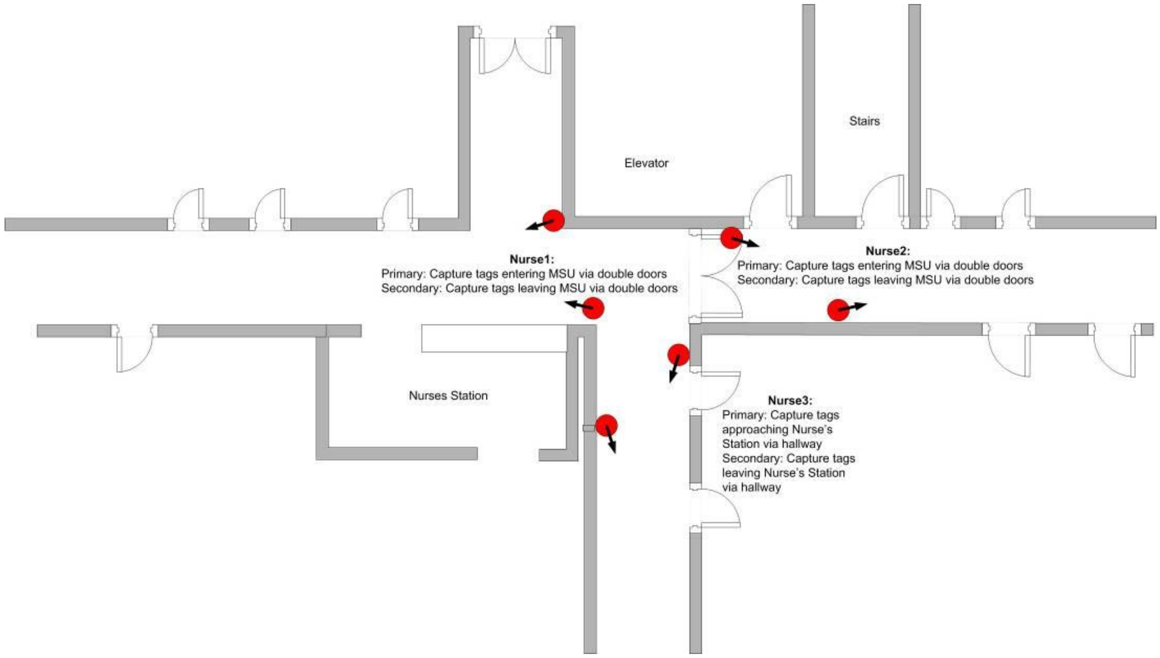

Figure 20: Diagram - MSU Nurse Station

Read Locations #4 and #5 – MSU Storage Rooms

The function of the antennas at Read Locations #4 and #5 was to provide capture of tagged equipment moving into and out of the MSU storage rooms. They also allowed for constant polling of medical equipment with any dwell time within the room. The addition of the two read stations outside the storage rooms allowed for confirmation of movement in either direction once it leaves the storage rooms. By tying into reads from the other read locations on the ward, the system enabled tracking of medical equipment movement while on the MSU and when the equipment entered or exited the ward.

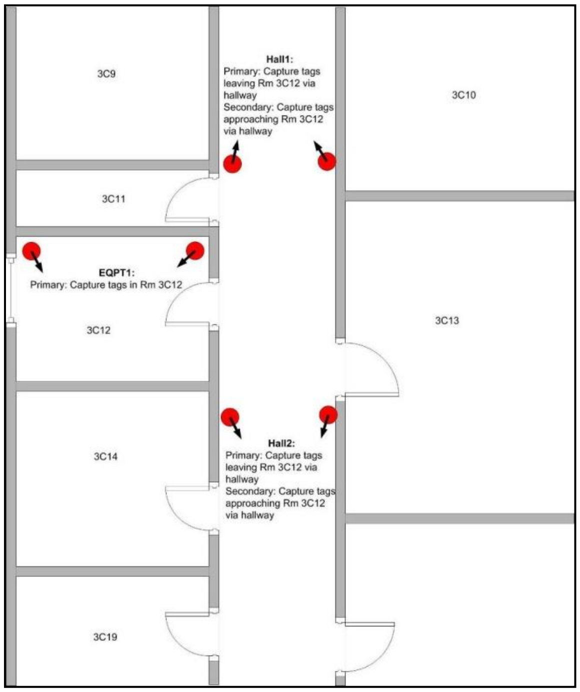

Figure 21: Diagram - MSU Storage Room

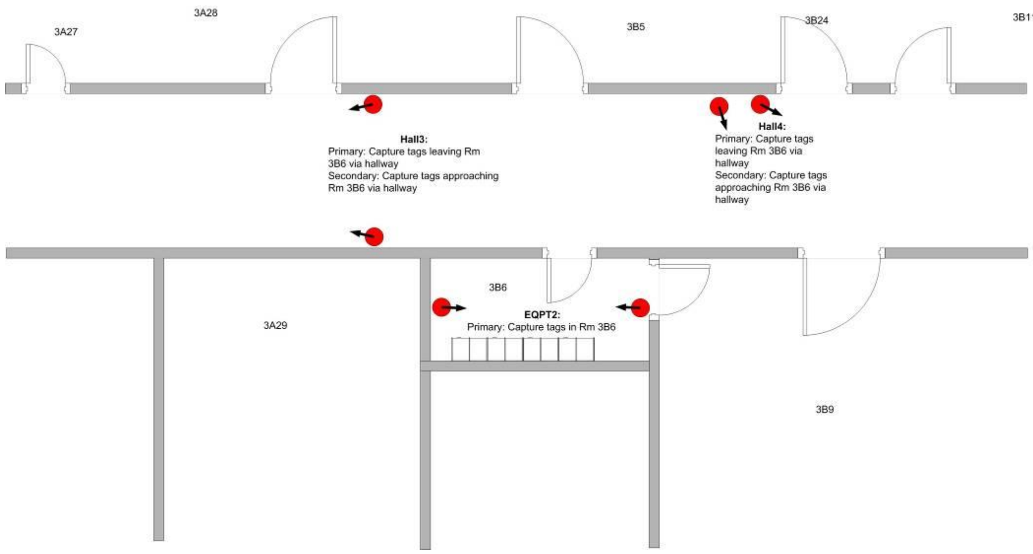

Figure 22: Diagram - MSU 3B6

Read Location #6 – MSU Bridge Entrance

The function of the antennas at Read Location #6 was to provide capture of tagged equipment moving into and out of the MSU ward via the bridge entrance.

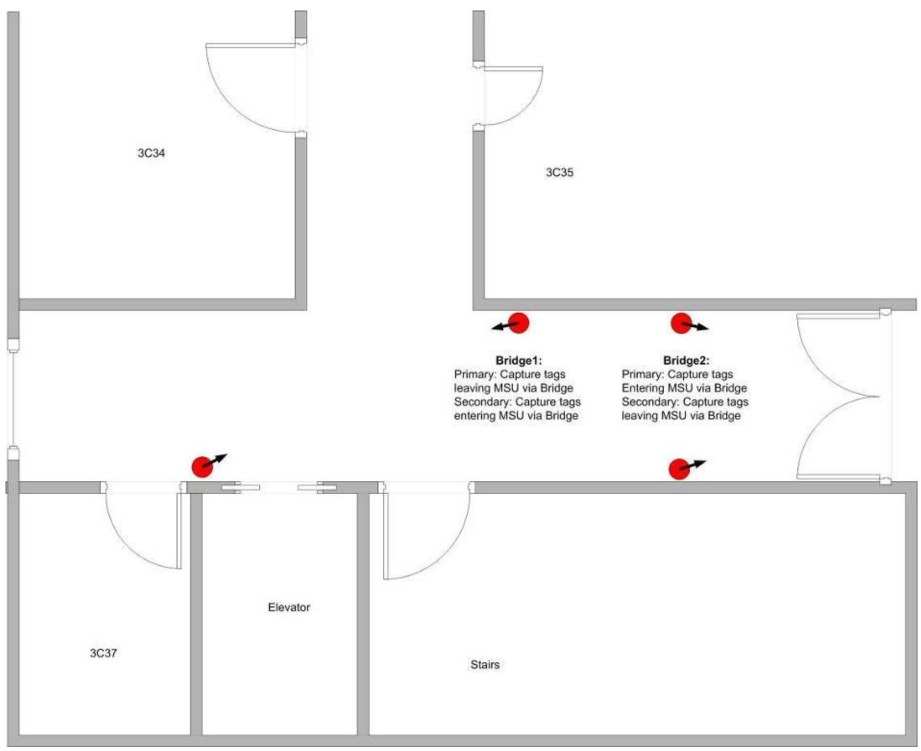

Figure 23: Diagram - MSU Bridge

7.5 Appendix E: Trial Data

MSU Storage Room 3B6

The MSU Storage Room 3B6 passive RFID system captured 100% of the entrance and exit events of the tagged equipment over the course of the trial. All "In" and "Out" (Entrance / Exit) events were captured by the system, for a 100% tag-read success rate over the course of the trial.

Table 4: Results - MSU Storage 3B6

Week	Item Name	RFID Tag Number	ECN Number	Exit Event	Entrance Event	Passed (Caught / Captured Tag-Read to Support Event)	Did Not Pass (Missed Tag-Read, Event)
1	Patient Transport Monitor	151	032038		Yes	PASSED	
1	Patient Transport Monitor	FB	032036		Yes	PASSED	
2	Patient Transport Monitor	FB	032036	Yes		PASSED	
2	Patient Transport Monitor	1C8	032040		Yes	PASSED	
2	Patient Transport Monitor	181	032033		Yes	PASSED	
3	Patient Transport Monitor	181	032033	Yes		PASSED	
3	Patient Transport Monitor	65	032037		Yes	PASSED	
3	Patient Transport Monitor	D0	032039		Yes	PASSED	
4	Patient Transport Monitor	1C8	032040	Yes		PASSED	
4	Patient Transport Monitor	65	032037	Yes		PASSED	
4	Patient Transport Monitor	D0	032039	Yes		PASSED	
5	Patient Transport Monitor	151	032038	Yes		PASSED	
6	Patient Transport Monitor	51	032035		Yes	PASSED	
7	Bladder Scan	B4	032308	Yes		PASSED	
7	Patient Transport Monitor	181	032033		Yes	PASSED	
7	Patient Transport Monitor	181	032033	Yes		PASSED	
7	Patient Transport Monitor	51	032035	Yes		PASSED	
8	Bladder Scan	B4	032308		Yes	PASSED	

MSU Storage Room 3C12

The MSU Storage Room 3C12 passive RFID system captured 81% of the entrance and exit events of the tagged equipment over the course of the trial. The table below indicates that 62 out of 77 "In" and "Out" (Entrance / Exit) events were captured by the system for an 81% tag-read success rate over the course of the trial. *** Storage Room 3C12Medical Equipment Read Rate Accuracy

- ✓ 42 Exit Events: 81%
- ✓ 35 Entrance Events: 80% success rate

Table 5: Results - MSU 3C12

Week	Item Name	RFID Tag Number	ECN Number	Exit Event	Entrance Event	Passed (Caught / Captured Tag-Read to Support Event)	Did Not Pass (Missed Tag-Read, Event)
1	Scale Tronix Patient Scale	38	035173	Yes		PASSED	
1	Abbott Life-Care Infuser	49	015020		Yes	PASSED	
1	Venaflow System	121	025978	Yes		PASSED	
1	Patient Transport Monitor	181	032033		Yes	PASSED	
1	Patient Transport Monitor	D0	032039		Yes	PASSED	
1	Venaflow System	66	025969	Yes		PASSED	
1	Patient Transport Monitor	65	032037		Yes	PASSED	
2	Infusion Pump	55	027487	Yes		PASSED	
2	Patient Transport Monitor	65	032037	Yes			MISSED
2	Venaflow System	66	025969		Yes	PASSED	
2	Infusion Pump	77	027516		Yes		MISSED
2	Infusion Pump	100	027486		Yes	PASSED	
2	Venaflow System	105	025975		Yes	PASSED	
2	Venaflow System	121	025978		Yes		MISSED
2	Infusion Pump	16C	27557	Yes		PASSED	
2	Patient Transport Monitor	181	032033	Yes		PASSED	
2	Venaflow System	1E	025970	Yes		PASSED	
2	Venaflow System	BD	025980	Yes		PASSED	
2	Patient Transport Monitor	D0	032039	Yes		PASSED	
2	Infusion Pump	DD	27489		Yes		MISSED
2	Infusion Pump	E9	027497	Yes		PASSED	
2	Patient Transport Monitor	FB	032036		Yes	PASSED	
3	Venaflow System	43	025979	Yes		PASSED	
3	Venaflow System	66	025969	Yes		PASSED	
3	Venaflow System	105	025975	Yes		PASSED	
3	Abbott Lifecare Infuser	14C	015033	Yes		PASSED	
3	Patient transport Monitor	181	032033		Yes	PASSED	

Week	Item Name	RFID Tag Number	ECN Number	Exit Event	Entrance Event	Passed (Caught / Captured Tag-Read to Support Event)	Did Not Pass (Missed Tag-Read, Event)
3	Feeding Pump	D2	032890	Yes			MISSED
4	Venaflow System	43	025979		Yes	PASSED	
4	Venaflow System	66	025969		Yes	PASSED	
4	Infusion Pump	77	027516	Yes			MISSED
4	Patient transport Monitor	181	032033	Yes		PASSED	
4	Patient Transport Monitor	1C8	032040		Yes	PASSED	
4	Venaflow System	C3	025977	Yes		PASSED	
4	Infusion Pump	F6	027514	Yes		PASSED	
4	Patient Transport Monitor	FB	032036	Yes		PASSED	
5	Venaflow System	43	025979	Yes		PASSED	
5	Venaflow System	66	025969	Yes		PASSED	
5	Feeding Pump	74	032626	Yes		PASSED	
5	Infusion Pump	97	027491	Yes			MISSED
5	Infusion Pump	98	027526	Yes		PASSED	
5	Venaflow System	105	025975		Yes		MISSED
5	Infusion Pump	109	027482		Yes		MISSED
5	Patient Transport Monitor	1C8	032040	Yes		PASSED	
5	Venaflow System	BD	025980		Yes	PASSED	
5	Infusion Pump	C5	027520		Yes		MISSED
6	Venaflow System	34	025974	Yes		PASSED	
6	Feeding Pump	74	032626		Yes	PASSED	
6	Infusion Pump	100	027486	Yes		PASSED	
6	Venaflow System	121	025978	Yes		PASSED	
6	Infusion Pump	1001	027521	Yes		PASSED	
6	Venaflow System	3B	025976	Yes		PASSED	
6	Venaflow System	9B	025972	Yes		PASSED	
6	Venaflow System	BA	025981	Yes		PASSED	
6	Venaflow System	BD	025980	Yes		PASSED	
6	Infusion Pump	C5	027520	Yes		PASSED	
6	Infusion Pump	DD	27489	Yes			MISSED
7	Venaflow System	34	025974		Yes	PASSED	
7	Infusion Pump	55	027487		Yes	PASSED	
7	Infusion Pump	100	027486		Yes	PASSED	
7	Infusion Pump	109	027482	Yes			MISSED
7	Venaflow System	121	025978		Yes	PASSED	
7	Infusion Pump	1001	027521		Yes		MISSED
7	Venaflow System	1E	025970		Yes	PASSED	
7	Venaflow System	3B	025976		Yes	PASSED	
7	Venaflow System	9B	025972		Yes	PASSED	

Week	Item Name	RFID Tag Number	ECN Number	Exit Event	Entrance Event	Passed (Caught / Captured Tag-Read to Support Event)	Did Not Pass (Missed Tag-Read, Event)
7	Venaflow System	C3	025977		Yes	PASSED	
8	Venaflow System	34	025974	Yes		PASSED	
8	Patient Transport Monitor	51	032035		Yes	PASSED	
8	Venaflow System	66	025969		Yes	PASSED	
8	Infusion Pump	97	027491		Yes	PASSED	
8	Infusion Pump	100	027486	Yes		PASSED	
8	Venaflow System	121	025978	Yes			MISSED
8	Infusion Pump	1001	027521	Yes			MISSED
8	MAC 5000 ECG Unit	2F	032096		Yes	PASSED	
8	Venaflow System	BD	025980		Yes	PASSED	
8	Infusion Pump	DD	27489		Yes	PASSED	

MERC Area

The MERC passive RFID system captured 89% of the entrance and exit events of the tagged equipment over the course of the trial. The table below identifies that 16 out of 18 “In” and “Out” (Entrance / Exit) events were captured by the system for an 89% tag-read success rate over the course of the trial. ** MERC Medical Equipment Read Rate Accuracy

- ✓ 13 Exit Events: 85%
- ✓ Entrance Events: 100%

Table 6: Results - MERC

Week	Item Name	RFID Tag Number	ECN Number	Exit Event	Entrance Event	Passed (Caught / Captured Tag-Read to Support Event)	Did Not Pass (Missed Tag-Read, Event)
1	Bed	86	026235	Yes		PASSED	
1	Infusion Pump	13F	031366	Yes		PASSED	
1	Infusion Pump	3C	034436	Yes			MISSED
1	Infusion Pump	D4	034437	Yes			MISSED
2	Bed	A6	020982	Yes		PASSED	
3	Vital Sign Monitor	4B	035198	Yes		PASSED	
3	Vital Sign Monitor	4E	035200	Yes		PASSED	
3	Vital Sign Monitor	8C	035199	Yes		PASSED	
3	Suction Unit (Aspirator)	B5	031953	Yes		PASSED	
4	Suction Unit (Aspirator)	B5	031953		Yes	PASSED	
4	Patient Transport Monitor	181	032033		Yes	PASSED	
5	No Activity This Week	____	____	____	____	____	____
6	Portable Defibrillator	9	033450	Yes		PASSED	
6	Portable Defibrillator	0E	033451	Yes		PASSED	
6	Patient Transport Monitor	151	032038		Yes	PASSED	
7	Portable Defibrillator	9	033450		Yes	PASSED	
7	Portable Defibrillator	0E	033451		Yes	PASSED	
7	Patient Transport Monitor	181	032033	Yes		PASSED	
8	Wheelchair	D8	N/A	Yes		PASSED	

7.6 Appendix F: Patient Transport Monitor History

Tag ID: 181, ECN: 032033, Description: Prodigy II Patient Transport Monitor

Code: Exit Event, Enter Event

Table 7: Results - Patient Monitor

Event	Date	Time
Entered 3C12	19-Jul	9:44
Left 3C12	25-Jul	14:16
Passed by Nurses Station (heading towards 3B6)	25-Jul	18:03
Passed by Nurses Station (heading back towards 3C12)	25-Jul	18:13
Entered 3C12	25-Jul	18:14
Left 3C12	25-Jul	21:44
Passed by Nurses Station (heading towards 3B6)	26-Jul	14:33
Entered 3B6	27-Jul	15:07
Left 3B6	28-Jul	9:22
Passed by Nurses Station (heading towards 3C12)	28-Jul	9:31
Passed by Nurses Station (heading back towards 3B6)	28-Jul	10:03
Entered 3B6	28-Jul	10:04
Left 3B6	28-Jul	16:39
Passed by Nurses Station (heading towards 3C12)	28-Jul	16:48
Passed by Nurses Station (heading back towards 3B6)	28-Jul	16:57
Entered 3B6	28-Jul	16:59
Left 3B6	29-Jul	1:18
Passed by Nurses Station (heading towards 3C12)	29-Jul	1:27
Passed by Nurses Station (heading back towards 3B6)	29-Jul	5:07
Entered 3B6	29-Jul	5:21
Left 3B6	29-Jul	9:11
Passed by Nurses Station (heading towards 3C12)	29-Jul	9:21
Passed by Nurses Station (heading back towards 3B6)	29-Jul	9:25
Entered 3B6	29-Jul	9:26
Left 3B6	29-Jul	17:30
Passed by Nurses Station (heading towards 3C12)	29-Jul	17:50
Passed by Nurses Station (heading back towards 3B6)	29-Jul	17:58
Entered 3B6	29-Jul	18:01
Left 3B6	1-Aug	7:24
Passed by Nurses Station (heading towards 3C12)	1-Aug	7:24
Entered 3C12	1-Aug	7:25
Left 3C12	2-Aug	13:46
Passed by Nurses Station (heading towards 3B6)	2-Aug	13:51
Passed by Nurses Station (heading back towards 3C12)	2-Aug	13:56
Entered 3C12	2-Aug	19:54
Left 3C12	3-Aug	21:09
Passed by Nurses Station (heading towards 3B6)	3-Aug	21:10
Entered 3B6	4-Aug	5:45
Left 3B6	4-Aug	13:12
Passed by Nurses Station (heading towards 3C12)	4-Aug	13:33
Entered 3C12	4-Aug	17:57
Left 3C12	5-Aug	9:06
Passed by Nurses Station (heading towards 3B6)	5-Aug	21:30
Passed by Nurses Station (heading back towards 3C12)	5-Aug	21:36
Entered 3C12	6-Aug	6:13
Left 3C12	6-Aug	9:28
Passed by Nurses Station (heading towards 3B6)	6-Aug	9:35
Passed by Nurses Station (heading back towards 3C12)	6-Aug	9:49
Entered 3C12	6-Aug	9:50
Left 3C12	6-Aug	16:53
Passed by Nurses Station (heading towards 3B6)	6-Aug	17:06
Passed by Nurses Station (heading back towards 3C12)	6-Aug	17:07
Entered 3C12	6-Aug	17:07
Left 3C12	7-Aug	9:24
Passed by Nurses Station (heading towards 3B6)	7-Aug	9:38
Passed by Nurses Station (heading back towards 3C12)	7-Aug	9:43

Event	Date	Time
Entered 3C12	7-Aug	9:44
Left 3C12	8-Aug	9:03
Passed by Nurses Station (heading towards 3B6)	8-Aug	9:29
Passed by Nurses Station (heading towards ICU)	8-Aug	9:30
Entered MERC	8-Aug	9:32
Left MERC	24-Aug	8:45
Passed by Nurses Station (heading towards 3B6)	24-Aug	8:48
Entered 3B6	24-Aug	8:49
Left 3B6	26-Aug	9:05
Passed by Nurses Station (heading towards 3C12)	26-Aug	9:06
Entered 3C12	26-Aug	14:07
Left 3C12	28-Aug	21:35
Passed by Nurses Station (heading towards 3B6)	29-Aug	1:14
Passed by Nurses Station (heading back towards 3C12)	29-Aug	1:20
Entered 3C12	29-Aug	6:11
Left 3C12	29-Aug	20:54
Passed by Nurses Station (heading towards 3B6)	29-Aug	20:55
Entered 3B6	30-Aug	5:11
Left 3B6	30-Aug	21:06
Passed by Nurses Station (heading towards 3C12)	30-Aug	21:31
Passed by Nurses Station (heading back towards 3B6)	31-Aug	00:28
Entered 3B6	31-Aug	1:19
Left 3B6	31-Aug	20:21
Passed by Nurses Station (heading towards 3C12)	31-Aug	20:59
Passed by Nurses Station (heading back towards 3B6)	31-Aug	21:11
Entered 3B6	1-Sep	9:16
Left 3B6	3-Sep	19:53
Passed by Nurses Station (heading towards 3C12)	4-Sep	5:09
Entered 3C12	4-Sep	5:40
Left 3C12	4-Sep	8:22
Passed by Nurses Station (heading towards 3B6)	4-Sep	8:38
Passed by Nurses Station (heading back towards 3C12)	4-Sep	13:05
Passed by Nurses Station (heading back towards 3B6)	4-Sep	13:16
Entered 3B6	4-Sep	17:44
Left 3B6	5-Sep	21:46
Passed by Nurses Station (heading towards 3C12)	5-Sep	17:36
Passed by Nurses Station (heading back towards 3B6)	5-Sep	19:29
Entered 3B6	6-Sep	1:28
Left 3B6	7-Sep	7:39

7.7 Appendix G: Interference **Important**

While the initial site survey did not indicate any environmental radio frequency issues in the selected trial zones, interference *was* detected between the passive RFID readers and an EKG machine. As a result, extensive interference testing was conducted on sixteen medical devices. Nine of the devices, such as wheelchairs, did not require testing. Mitigation of the interference was successful by attenuation (significantly reducing the power-output level) of the RFID-readers while still allowing for successful read rates of the passive RFID system. The testing and approvals took six weeks. This finding is provided in this report as it has implications for not only future passive RFID systems but any wireless implementation within a hospital facility.

Interference Testing

During conduct of the trial installation and preparation, interference was detected between the passive RFID readers and the MAC 5000 electronic cardiograph machine. Consequently, a comprehensive RFID interference test was conducted by the RFID Solutions Center, an EPC-Global Accredited Performance Test Center, and representatives from Wright-Patterson Hospital on sixteen clinical devices. Twelve of the devices were tested in Alien's certified testing laboratory and four of the devices were tested within Wright-Patterson.

Two distinct testing procedures were used during the testing process. Phase one used “Screen Testing” in which the medical device was bombarded at full RF power at close range to determine if any negative impact to the medical device occurred. Screen Testing was followed by “Investigative Testing” where calibration settings on RFID equipment were manipulated to eliminate interference issues discovered during screen testing. The results were then tabulated to ensure sufficient enabling RFID tracking capabilities at an acceptable performance level and compared with documented specification from the medical equipment manufacturers.

As a result of this testing, fourteen devices (showed in Exhibit III-5) showed no interference. Two devices showed interference during the testing process**:** the MAC 5000 ECG machine by GE Medical, and the Blood-Flow Monitor by Graham-Field Inc. RFID reader attenuation (reducing power) fully negated the interference issues with the MAC 5000. For the recommenced trial, the RFID readers ran at a 5 db attenuation (power reduction) level which translates to operating at about a ¼ power of normal operational use. At this 5db attenuation level, the Blood Flow monitor’s interference/static symptoms fully subsided once it was beyond eight feet of the nearest RFID read point. Examination of the clinical use of the Blood Flow Monitor indicated that it is only used in patient rooms, none of which are within eight feet of an RFID read point and therefore would not interfere with patient care.

Table 8: Interference-Tested Equipment

Nomenclature	Manufacturer/Distributor	Model Number
Thermo Meter	Welch Allyn	Model 690
Thermo Meter	Welch Allyn	Model 679
Pulse OXIMETER	BCI	Model 3301
Suction Unit	Laerdal	Model LSU 4000
Physiological Monitor	Colin Medical Inst. Corp.	Prodigy II 2240
Circulatory Assist Unit	Aircast	Venaflow - Model 30A
External Defibrillator	Zoll Medical	Model M
Electrocardiograph , Multi-channel, interpretive	GE Medical	MAC 5000
Infusion Pump, Patient Controlled Analgesic	Abbott	Model 172
Enteral Feeding Pump	Novartis	Nutrition Selctflo mode
Electronic Infra Red Skin Thermometer	Exergen Corp.	Model TAT 5000
Infusion Pump, General Purpose	Alaris	Model 7130B
Physiologic Monitoring System, Acute Care	Welch Allyn	Model Propaq 102EL
Ultrasonic Blood Floe Detector	Graham-Field Inc.	Model ES100VX
Bladderscan : Diagnostic Ultrasound Inc.	Unknown Mfg	Unknown Model
Transport Ventilator : Impact Instruments	Unknown Mfg	Unknown Model

Required Interference Mitigation

As a result of the interference issues uncovered during the course of this trial, we have determined that *prior to* the physical installation of a passive RFID system at *any* given healthcare facility, preliminary interference testing must be done between that passive RFID system and all critical-care devices that are used at that facility. This must be done to ensure that the intended passive-RFID system does not adversely affect the performance of any devices that are critical to patient care.

- This testing should be performed off-site, so that *active* patient care devices that are currently in use by patients are not interfered with during the testing process. If this is not feasible, then a remote/isolated location within the facility should be selected for testing.
- Once safe power-reduction levels of RFID equipment and proper separation distances between RFID equipment and patient-care devices have been determined through testing, all future additional patient-care devices that are added to that facility (newly introduced makes and models) should also be tested to this specification before being deployed for use.

7.8 Appendix H: Recommendations and associated Requirements

Based on the results of the trial, it is prudent to recommend a hospital-wide roll-out of a working passive RFID system that tags medical equipment and devices used through the facility. This roll-out should enhance a number of features of the trial system and would include the following enhancements and requirements.

Solution Design Enhancements

- ✓ Design the system to adhere to the same type of *zonal coverage patterns* used during the trial
- ✓ Avoid full-zonal coverage (room by room RFID coverage across all rooms in all buildings of a given facility), as this is not a cost-effective solution design approach
- ✓ Adhere to those zone types that were used during the course of the trial (conglomeration-point coverage areas for tracking inventory and in/out activity, 'directional checkpoint' coverage areas for traffic-flow monitoring and 'last seen' *read* capability)
- ✓ Cover all floors at a given facility (or within a given building) by having *read-checkpoints* set up at each floor's portals (stairways and elevator bays); note that directionality will not be required at these floor-portal zones if all floors are covered. Directionality will be determined on an 'elevator bay to elevator bay' basis, or on a 'stairway zone to stairway zone' basis, when items transfer from floor to floor
- ✓ Cover all important conglomeration points on each floor (storage rooms, equipment maintenance and repair areas, etc.), and apply directional capabilities for *in and out* determination at each of these zones
- ✓ Set up traffic-flow monitoring checkpoint stations (with directional-determination capabilities) incrementally on each floor (I.e., every 100-200 ft. in the hallways).
- ✓ With the above-mentioned solution-design approach, you will be able to determine at all times which floor an item is on, and whether or not that item is in use (the latter, by virtue of the fact that it is or is not in a storage or maintenance repair area). When an item is in use, you will be able to determine its' location, down to the resolution of the *traffic-flow monitoring zone* separation distances.

Software Enhancements

- ✓ Interface with DMLSS - This is a significant requirement that would require coordination at the MHS level to develop a standard RFID interface for this functionality
- ✓ Provide back-end software capabilities to determine an item's zonal location for the end-user (i.e., directionality-determination shall be done automatically by the software, and presented to the end-user)

Interference-Mitigation Requirements

- ✓ As a safety requirement, ensure that necessary measures are always taken to determine, account for and eradicate potential interference issues between RFID equipment and patient-care devices, at this or any other healthcare facility where RFID may be deployed for use **(see section 7.7, appendix G)**