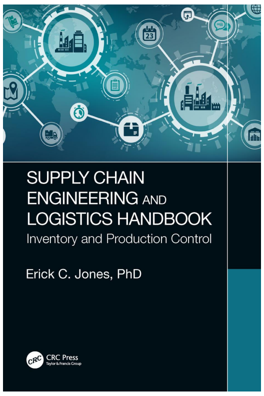

Supply Chain Engineering and Logistics Handbook Inventory and Production Control

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The Internet of Things (IoT) Technologies and the Tracking of Supply Chain Assets

Publication details
https://test.routledgehandbooks.com/doi/10.1201/9781315159096-13
Erick C. Jones
Published online on: 05 Dec 2019

13

The Internet of Things (IoT) Technologies and the Tracking of Supply Chain Assets

Erick C. Jones

In God We Trust. All Others Must Bring Data.

W. Edwards Deming

13.1 Introduction to AIT Technologies

Generally, in order to utilize technology effectively, one should initially understand it. Radio frequency identification (RFID) technologies fall into a group of technologies described as automatic information technologies (AITs), which are complex entities that can be utilized in many ways. Military operators will have to use knowledge, insight, and creativity to make effective decisions on how and when to use these systems. Two of these pervasive technologies RFID and barcodes are considered in this text. Due to this fact, this chapter describes the AITs and provides a historical perspective on barcodes and RFID technologies. The perspective provided will help military personnel and contractors, and other managers envision an organized plan that supports effective decisions and can be gained by reviewing historical events.

13.2 Automatic Information Technologies

In this text when we describe AITs, we describe a group of technologies that are generally associated with automatic data capture (ADC) in both military and commercial applications. Other technologies may be included as AITs, but we present a list that this text focuses upon.

The AIT/ADC includes:

1. Barcodes (Linear/2D/3D)
2. RFID (Active/Passive/Semi-Passive)
3. Radio Frequency Data Capture (RFDC)
4. Real-Time Location Systems (RTLSs)
5. Satellite tags/global positioning system (GPS) (Not in Diagram)
6. Microelectromechanical system (MEMS)
7. Contact Memory Buttons
8. Biometrics
9. Common Access Card
10. Optical Character Recognition (OCR).

With such a large variety of technologies to choose from, it is important for one to consider that the strategic purpose or operational requirements should drive the technology that is chosen. The technology

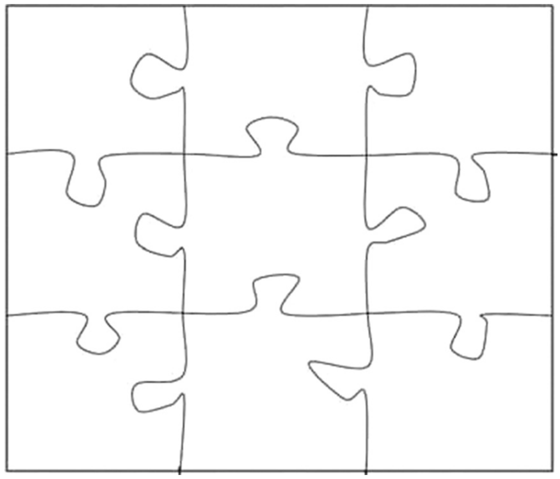

FIGURE 13.1 AIT Jigsaw.

should not be chosen based upon technical bias. Below is a brief description of each technology. We first generally describe the technologies. We will then describe commonly accepted definitions. In this text, we utilize a leading authority on automatic identification (AutoID), Advanced Integrated Manufacturing (AIM), for defining these common ADC technologies (Figure 13.1).

13.2.1 AIM Global

AIM is the industry association and worldwide authority on AutoID and data collection technologies. AIM members are providers and users of technologies, systems, and services that capture, manage, and integrate accurate data into larger information systems that improve processes enterprise-wide. Serving members in 43 countries for 35 years, the association has developed key technical specifications and guidelines that support the use of AutoID and mobile IT solutions.

AIM actively supports the development of technology standards, guidelines, and best practices through its Technical Symbology Committee (TSC) and RFID Experts Group (REG), as well as through participation at the industry, national (American National Standards Institute (ANSI), and international (International Organization of Standardization (ISO)) levels.

AIM has an active educational and government relations focus, providing accurate and unbiased information on data collection technologies and the markets they serve. For more information about AIM and its members and services, please visit www.aimglobal.org or www.rfid.org.

13.2.2 Barcodes

Generally, a barcode is an optically read representation of data in the form of lines and spacing of parallel lines. The line forms are generally categorized as one-dimensional (1D) barcodes. Other representations include geometric patterns such as dots, squares, and hexagons and are categorized as two-dimensional (2D) matrix codes. The codes are read by barcode readers that recognize the patterns. We have included Direct Part Marking (DPM) and Electronic Article Surveillance (EAS) samples for barcoding.

13.2.3 Direct Part Marking

DPM is a technology used to produce two different surface conditions on an item. These markings can be created by laser etching, molding, peening, etc. Traditional print quality measures are based on the assumption that there will be a measurable difference between dark and light elements of a symbol. Because DPM symbols frequently do not have sufficient contrast between elements intended to be dark and light, it is often necessary to provide specialized lighting in order to produce highlights or shadows in order to distinguish the various elements of the symbol. AIM Global shows examples of these technologies via their website.

13.2.4 DPM Quality Guidelines Document

Acknowledging that current ISO print quality specifications for matrix symbologies and 2D print quality are not exactly suited for DPM symbol evaluation, an ad-hoc committee under the supervision of the AIM Technical Symbology Committee developed a guideline to act as a bridge between the existing specifications and the DPM environment in order to provide a standardized image-based measurement method for DPM that is predictive of scanner performance.

The document describes modifications which are to be considered in conjunction with the symbol quality methodology defined in ISO/IEC 15415 and 2D symbology specifications. It defines alternative illumination conditions, modifications to the measurement and grading of certain parameters, and the reporting the grading results.

13.2.5 Electronic Article Surveillance

EAS is a technology used to identify items as they pass through a gated area. Typically, this identification is used to alert someone of the unauthorized removal of items from a store, library, or data center.

There are several types of EAS systems. In each case, the EAS tag or label is affixed to an item. The tag is then deactivated when the item is purchased (or legally borrowed) at the checkout desk. When the item is moved through the gates (usually at a door to the premises), the gate is able to sense if the tag is active or deactivated and sound an alarm if necessary.

EAS systems are used where there is a chance of theft from small items to large. By placing an EAS tag on an item, it is not necessary to hide the item behind locked doors which makes it easier for the consumer to review the product.

Today's EAS source tagging, where the tag is built into the product at the point of manufacture or packaging, has become commonplace. This makes the labeling of goods unnecessary, saving time and money at the store.

13.3 Radio Frequency Identification

RFID is a generic term that is used to describe a system that transmits the identity (in the form of a unique serial number) of an object or person wirelessly, using radio waves. It's grouped under the broad category of AutoID technologies. RFID is in use all around us. If you have ever chipped your pet with an ID tag, used EZPass through a tollbooth, or paid for gas using SpeedPass, you've used RFID. In addition, RFID is increasingly used with biometric technologies for security. Unlike ubiquitous UPC barcode technology, RFID technology does not require contact or line of sight for communication. RFID data can be read through the human body, clothing, and non-metallic materials.

13.3.1 Components

A RFID system consists of the following main components:

- An antenna or coil
- A transceiver (with decoder) also referred to as a reader
- A transponder (RFID tag) electronically programmed with unique information (generally the electronic product code (EPC))
- Host computer System with a database to store the RFID reads
- Transceiver software and logic (often called Edgeware).

The *antenna* emits radio signals to wake up or excite the tag; it may in the same signal be able to read and write data to it.

- The reader emits radio waves in ranges of anywhere from one inch to 100 ft or more, depending upon its power output and the tag frequency. When a tag maneuvers through the correct electromagnetic zone which has the same frequency, it detects the reader's activation signal.
- The reader decodes the data encoded in the RFID tags integrated circuit, and the data is passed to the host computer for processing.

The purpose of an RFID system is to enable data to be transmitted by a portable device, called a tag, which is read by an RFID reader and processed according to the needs of a particular application. The data transmitted by the tag may provide identification or location information or specifics about the product tagged, such as price, color, date of purchase, etc. RFID technology has been used by thousands of companies for a decade or more. RFID quickly gained attention because of its ability to track moving objects. As the technology is refined, more pervasive—and invasive—uses for RFID tags are in the works.

Most manufacturers of RFID tags create the tags with microchip attached to a radio antenna mounted on a substrate. The chip generally stores generally 2 kB of data. To retrieve the data stored on an RFID tag, you need a reader. A typical reader is a device that has one or more antennas that emit radio waves and receive signals back from the tag. The reader then passes the information in digital form to a computer system.

13.3.2 Radio Frequency Data Capture

Radio frequency transmission has been with us since Guglielmo Marconi first demonstrated wireless communications a century ago. Within 30–40 years of Marconi's discovery, radios had become a fixture in nearly every U.S. household. However, it has been only within the last half-dozen years that wireless data transmission has come into its own in a business environment.

RFDC first appeared in warehouses and distribution centers as an enabling technology for automatic identification and data capture (AIDC) implementations, where hardwiring was unfeasible and/or real-time updating of the host database was critical. Early applications typically ran on PCs or controllers, scattered throughout a facility, which were interfaced to what was essentially a batch-oriented host. Those early systems were costly, quirky, and limited in transaction processing. However, they often made ADC a reality in environments where hardwired systems were impossible. Further, RFDC offered certain advantages over hardwired AIDC systems—interactivity and real-time updates of inventory, shipments, or manufacturing applications—that companies could turn to their own competitive advantage.

Technology improvements kept pace with RFDC's steady growth, so that present-day RFDC-based systems provide powerful, sophisticated, and reliable wireless solutions for a wide variety of both local-area and wide-area networked applications.

Five frequently cited benefits to using Radio Frequency Data Communication are increased database accuracy at all times, reduced paperwork, real-time operations, higher productivity, and shorter order response times.

13.3.3 Real Time Locating System

Real-time visibility into exact locations of containers and cargo has never been as important as today with increased movement of cargo from offshore, the need to move it quickly to final destinations, and new security requirements. Today's wireless technology provides critical visibility into supply chain (SC) activities, delivering benefits to carriers, shippers, and customers.

RTLSs are fully automated systems that continually monitor the locations of assets and personnel. An RTLS solution typically utilizes battery-operated radio tags and a cellular locating system to detect the presence and location of the tags. The locating system is usually deployed as a matrix of locating devices that are installed at a spacing of anywhere from 50 to 1,000 ft. These locating devices determine the locations of the radio tags.

The systems continually update the database with current tag locations as frequently as every several seconds or as infrequently as every few hours for items that seldom move. The frequency of tag location updates may have implications for the number of tags that can be deployed and the battery life of the tag. In typical applications, systems can track thousands of tags simultaneously, and the average tag battery life can be 5 or more years.

13.3.4 Satellite Tags with GPS

GPS consist of a series of satellites orbiting the Earth and receivers. GPS works by calculating the distances from a receiver to a number of satellites. With each distance between a receiver and satellite, the number of possible locations is narrowed down, until there is only one possible location. A receiver must calculate its distance from at least three satellites to determine a location on the surface of the Earth. However, four satellites are usually used to increase the location accuracy. This process of location would be controlled by the positioning module of GPS. An average GPS positioning and navigation system would also have the following modules:

- Digital Map Database
- Map Matching
- Route Planning and Guidance
- Human–Machine Interface
- Wireless Communication.

There are three positioning technologies that can be used: radio wave-based positioning, dead reckoning, and signpost. The use of GPS for navigation can have direct and indirect impacts on Intelligent Transportation Systems. GPS navigation systems can provide information about local surroundings. Also, emergency personnel can be provided with a precise location for situations, thus reducing response times. Asset tracking is one of the most popular uses of GPS. One of the limitations of GPS is that receivers cannot communicate with satellites when indoors.

13.3.5 Microelectromechanical SYSTEM

MEMS is a micro-electromechanical, micro-electro-mechanical, or microelectromechanical system that is very small and merges at the nanoscale or *nanoelectromechanical system* (NEMS) and other *nanotechnology*. A good resource MEMSNET, an information resource for the MEMS and Nanotechnology development community further describes MEMS "as *micromachines* (in Japan), or Micro Systems Technology—MST (in Europe)". MEMSs are separate and distinct from the hypothetical vision of *molecular nanotechnology* or *molecular electronics*. MEMSs are made up of components between 1 and 100 μm in size (i.e., 0.001–0.1 mm), and MEMS devices generally range in size from 20 μm (20 millionths of a meter) to a millimeter. "The promise that is available for MEMS is that together with silicon-based microelectronics and micromachining technology, the popularized idea of a computer system-on-a-chip is feasible." MEMSNET provides some futuristic ideas such as "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" (www.memsnet.org/mems/what-is.html).

13.3.6 Contact Memory Buttons

13.3.6.1 Contact Memory

Contact memory technology is ideal for use in harsh industrial applications and in situations that would render barcodes unreadable or impractical. Buttons can mark hazardous and radioactive waste for long-term storage, track the maintenance of airplane brakes, and store repair diagrams. Attached to the ears of livestock, buttons track the animals from birth through processing, and carry data on feed and antibiotic use. Contact memory technology is well suited to guard tour and access control applications in which users can access secure areas conveniently. Versatile touch/button technology can be used in healthcare to create records and match mothers and newborns or to track items along an assembly line and to store manufacturing history.

13.3.6.2 Biometrics

Biometrics are automated methods of recognizing a person based on a physiological or behavioral characteristic. Among the features measured are face, fingerprints, hand geometry, handwriting, iris, retinal, vein, and voice.

Biometric technologies are becoming the foundation of an extensive array of highly secure identification and personal verification solutions. As the level of security breaches and transaction fraud increases, the need for highly secure identification and personal verification technologies is becoming apparent.

The need for biometrics can be found in federal, state and local governments, in the military, and in commercial applications. Enterprise-wide network security infrastructures, government IDs, secure electronic banking, investing and other financial transactions, retail sales, law enforcement, and health and social services are already benefiting from these technologies. Biometric-based authentication applications include workstation, network, and domain access, single sign-on, application logon, data protection, remote access to resources, transaction security and Web security. Trust in these electronic transactions is essential to the healthy growth of the global economy. Utilized alone or integrated with other technologies such as smart cards, encryption keys, and digital signatures, biometrics are set to pervade nearly all aspects of the economy and our daily lives. Utilizing biometrics for personal authentication is becoming convenient and considerably more accurate than current methods (such as the utilization of passwords or PINs). This is because biometrics:

- Links the event to a particular individual (a password or token may be used by someone other than the authorized user)
- Is convenient (nothing to carry or remember)
- Accurate (it provides for positive authentication)
- Can provide an audit trail
- Is becoming socially acceptable and cost effective.

13.3.6.3 Common Access Cards

When we use the term “card technologies” or “smart cards”, what do we mean? The easy answer is—any technology that can be placed on a card. Typically, we think of our credit or bank card, but there are other sizes and materials used for different applications. The card can be made of plastic (polyester, PVC, or some other materials) or paper or even some amalgamation of materials. The common point is that the card is used to provide “access” to something, and it includes some form of AIDC technology.

There are currently three main technologies we think of when we mention card technologies:

- Magnetic stripe
- Smart cards
- Optical cards.

Other technologies can be put on cards as well (such as barcodes, touch memory, etc.). Often the card will have printing on it, which may involve technologies such as Dye Diffusion Thermal Transfer (D2T2) direct-to-card printing.

13.3.6.4 Optical Character Recognition

Optical Character Recognition (OCR) is used in high-volume financial applications such as payment processing, check reconciliation, and billing. It is also commonly used for high-volume document management in the insurance and healthcare industries. The technology is frequently found in libraries, publishing houses, and wherever printed text must be entered into a computer. OCR is also used in heavy-duty manufacturing environments for reading direct-marked, human-readable part numbers. The pharmaceuticals industry uses a variation of OCR called optical character verification (OCV) to assure that critical human-readable lot and date numbers cannot be misread.

13.3.6.5 Optical Mark Recognition

Optical Mark Recognition (OMR) is used for standardized testing as well as course enrollment and attendance in education. Human resource departments across industries use OMR for applications such as benefits enrollment, employee testing, change of employee status, payroll deductions, and user training. Healthcare providers use the technology for registration and surveys, and medical labs use it for patient evaluations and tracking supply orders and lab services. OMR is also used for time and attendance, labor tracking, inventory management, voting applications, exit surveys, polling, and all manner of questionnaires and evaluation studies. Because it is easy to use and cost effective for opinion tracking, the technology has become a tool for on-location and direct-mail marketing.

13.3.6.6 Machine Vision

Traditional machine vision systems continue to be used for quality inspection, gauging, and robotic assembly in the automotive, electronics, aerospace, healthcare, and metal industries among others. These systems may also incorporate barcode reading. The next generation of 2D dedicated vision-based scanners are being used for quality control, work in process (WIP), and high-speed sortation in industries such as electronics, automotive, and mail and package delivery. The pharmaceutical industry is also using 2D scanning systems to reconcile packaging, inserts, and labels on their packaging lines in order to satisfy the FDA's Current Good Manufacturing Practice (CGMP) regulations.

13.3.6.7 Voice

Voice recognition is commonly used in the automotive industry for various manufacturing and inspection applications. It is also used in warehousing and distribution to track material movement in real time, in the transportation industry for receiving and transporting shipments, in laboratory work, and in inspection and quality control applications across all industries.

13.3.6.8 Magnetic Ink Character Recognition

Magnetic Ink Character Recognition (MICR) is most commonly used to encode and read information on checks and bank drafts to speed clearing and sorting. It is also effective for uncovering fraud, such as color copies of payroll checks or hand-altered characters on a check, both of which are easily detected by the absence of magnetic ink. Fast clearing and sorting, as well as fraud detection, benefits customers, financial institutions, and retail establishments.

Though this s a long list of AITs, it is not comprehensive due to the fact that other technologies are becoming available as this book is being published and distributed. For this book's purposes, we focus upon three main technologies: barcodes, RFID/RTLS technologies, and satellite technologies.

13.3.7 History of RFID

A sense of history in RFID is important for the following reasons. Some RFID technologies have stood the test of time and have become more pervasive in the SC. Other RFID technologies have been utilized in other industries such as animal tracking and present unique advantages. The convergence of RFID systems has been theorized to create innovations in current industries and led to the creation of new industries. Given that the history of RFID is integrated with the history of other ADC devices such as barcodes, we approach chronicling RFID history in following ways.

First, we investigate the development of data acquisition device usage in the distribution and logistics. Second, we overlay the development history of RFID technologies for SC activities. Finally, we introduce future plans for RFID technologies in logistics operations.

The roots of RFID technology can be traced back to World War II (WWII). The radar, which had been discovered in 1935 by Scottish physicist Sir Robert Alexander Watson-Watt, was utilized by all combatants in the war (Germans, Japanese, Americans, and British) to identify aircraft, but there was no unique identification for the aircraft. The main problem with radar was there was no way to identify which planes belonged to the enemy and which were a country's own planes returning from a mission.

The Germans discovered that if pilots rolled their planes as they returned to base, it would change the radio signal reflected back. This crude method alerted the radar crew on the ground that these were German planes and not Allied aircraft. This plane "roll" created a uniquely identifiable signal that acted in essence as a unique reflected signal. This principle is what the base's passive RFID systems are based upon.

Later, Watson-Watt headed a secret project by the British to develop the first active identify friend or foe (IFF) system. A transmitter was placed on each British plane. When the transmitter received signals from radar stations on the ground, it began broadcasting a signal back that identified the aircraft as friendly. RFID works on this same basic concept. A signal is sent to a transponder which wakes up and either reflects back a signal (passive system) or broadcasts a signal (active system).

Advances in radar and radio frequency (RF) communication systems continued through the 1950s and 1960s. Scientists and academics in the United States, Europe, and Japan did research and presented papers explaining how RF energy could be used to identify objects remotely.

Companies began commercializing anti-theft systems that used radio waves to determine whether an item had been paid for or not. EAS tags are still used in retail packaging today at retailers such as JC Penney and SEARS in which they use a 1-bit tag. The bit is either on or off. When someone pays for the item, a cashier deactivates the tag and the bit is turned off, and a person can leave the store. In contrast, if the person doesn't pay and tries to walk out of the store, readers at the door detect the tag and sound an alarm.

13.3.8 Prior to IFF

Though many focus on the WWII as the beginning of RFID development, we will explore other events that contribute to theoretical understanding of RFID technologies. Given that some of the RFID technologies do not include passive, active, and semi-active technologies, we provide other historical events that will allow the student to investigate and create investigative thought on RFID technologies.

Many scientists believe at the beginning of time that electromagnetic energy created the universe often referred to as the "Big Bang" Theory. Due to the fact that most RFID technologies use electromagnetic energy as the source of energy, this Big Bang may be considered the beginning of RFID technologies. Benjamin Franklin explored electromagnetism with his experiments in electricity in the 1700s. In the 1800s, Michael Faraday and James Maxwell contributed theories on electricity and relationship of light and magnetic fields on electromagnetic energy respectively. Michael Faraday, English scientist, explored relationship of light, radio waves, and electromagnetic energy. In 1864, James Maxwell, Scottish physicist, published theory on electromagnetic fields which concluded that electric and magnetic energies travel in transverse waves moving at the speed of light.

Later in the 1800s, in1887, Heinrich Rudolf Hertz, German physicist, confirmed Maxwell's theories and added theories about electromagnetic waves (radio waves) which showed as long transverse waves that travel at the speed of light and can be reflected, refracted, and polarized like light. Also, Hertz was the first credited for transmitting and receiving radio waves, and his demonstrations were later duplicated by Aleksander Popov of Russia. Another key breakthrough for radio transmission was when Guglielmo Marconi successfully transmitted a radiotelegraphy across the Atlantic Ocean.

Now in the 20th century we have in 1906 Ernst F.W. Alexanderson discover the first continuous wave (CW) radio generation and transmission of radio signals which signaled the beginning of modern radio communications where all aspects of radio waves controlled.

The Manhattan project at Los Alamos Scientific Laboratory in 1922 was attributed to the birth of the radar detection. The project described how the radar sends radio waves for detecting and locating an object by the reflection of the radio waves. The refection can determine the position and speed of an object. Given that RFID is a combination of radio broadcast technology and radar, the convergence of these disciplines allowed for future RFID development. Scottish physicist Sir Robert Alexander Watson-Watt was considered to be the inventor of the modern radar system in 1935.

In 1945, historians theorize that the first known device may have been invented by Thermin as a reporting espionage tool for the Russian Government in 1945, the device was the first "bug" or covert listening device. This device was the first to use inducted energy from radio waves of one frequency to transmit an audio signal to another. This made the device difficult to detect, as it did not radiate any signal unless it was being remotely powered and listened to, and endowed it with (potentially) unlimited operational life.

This bug was embedded in a two-foot wooden replica of the Great Seal of the United States and presented to the American ambassador in Moscow, Averell Harriman, by Russian schoolchildren in 1946. This is currently on display at the National Security Agency (NSA), National Cryptologic Museum. The bug hung prominently for years, at least part of the time in the ambassador's study, before a tiny microphone was found in the eagle by a professional bug sweeper using a marta kit, which happened to catch a signal from it while it was being used.

During George F. Kennan's ambassadorship in 1952, a routine security check discovered that the seal contained a microphone and a resonant cavity which could be stimulated from an outside radio signal. George Kennan's memoirs describe the event. In a theme now familiar, Kennan relates that Spaso House had been redecorated under Soviet supervision, without the presence of any American supervisors, giving them opportunity "to perfect their wiring of the house." "The ordinary, standard devices for the detection of electronic eavesdropping revealed nothing at all", but technicians decided to check again, in case our detection methods were out of date. The novelty of the Great Seal bug, which was hung over the desk of our Ambassador to Moscow, was its simplicity. It was a simple resonate chamber, with the front wall that moved and changed the dimensions of the chamber when sound waves struck it. It had no power pack, wires, and no batteries. An ultra-high-frequency signal beamed to it from a van parked near the building was reflected from the bug, after being modulated by sound waves from conversations striking the bug's diaphragm.

13.3.9 How the Great Bug Seal Worked

The Ultimate Spy Book by H. Keith Melton further details how the Great Bug Seal worked. It features a bald eagle, beneath whose beak the Soviets had drilled holes to allow sound to reach the device. Western experts were perplexed on how the device, also known as the "Thing", worked, because it had neither batteries nor electrical circuits. Peter Wright of British intelligence discovered how it operated and later produced a copy of the device for use by both British and American intelligence. The thing was initiated when a radio beam aimed at the antenna from a source outside of the building was sent. Then the sound wave struck the diaphragm causing variations in the amount of space (and the capacitance) between it and the tuning post plate. These variations altered the charge on the antenna, creating modulations in the reflected radio beam. These were picked up and interpreted by the receiver.

13.3.10 Research on RFID

One of the first works exploring RFID was the paper by Harry Stockman, entitled "Communication by Means of Reflected Power" (Proceedings of the IRE, pp. 1196–1204, October 1948). This transcript discussed the basic problems of researching "reflected-power" communication but discussed the usage of the technology. It also predicted that "…considerable research and development work has to be done before the remaining basic problems in reflected-power communication are solved, and before the field of useful applications is explored". For this prediction to become valid, advances in transistor technologies, integrated circuits, microprocessor, development of communication networks, and computing power had to happen over the next 30 years would spur cost economics of RFID-type technologies.

Also, in the 1950s other technical developments in radio and radar along with the IFF exploration of long-range transponder systems for identification include FL Vernon's "Application of the microwave homodyne" and DB Harris's "Radio transmission systems with Modula table passive transponder". These developments also led to future patents for RFID technology.

13.3.11 In the 20th Century

In the 1960s, RF Harrington studied the electromagnetic theory related to RFID papers, "Field Measurements using active scatterers", "Theory of loaded scatterers" in 1963–1964, Robert Richardson's "Remotely activated radio frequency powered devices" in 1963, Otto Rittenbacks's "Communication by radar beams" in 1969, HH Vogelmans's "Passive data transmission techniques utilizing radar beams" in 1968, and JP Vindings's "Interrogator-responder identification system" in 1967.

Commercial Activities were beginning in the 1960s. Sensormatic and Checkpoint were founded in the late 1960s. Other companies such as Knogo developed EAS equipment to counter theft using 1-bit tags. Fundamentally, the presence or absence of a tag was detected, and the tags were made inexpensively and could provide effective anti-theft measures. Most of these systems used microwave or inductive technology. This EAS technology was the first widespread use of RFID technology.

13.3.12 The First RFID Patents

The first U.S. patents for RFID tags were from Mario W. Cardullo and Charles Watson in 1973. Mario W. Cardullo received the first U.S. patent for an active RFID tag with rewritable memory on January 23, 1973. That same year, Charles Walton, a California entrepreneur, received a patent for a passive transponder used to unlock a door without a key. The electronic door lock operated with a card that communicated with an embedded transponder that communicated a signal to a reader near the door. When the reader detected a valid identity number stored within the RFID tag, the reader unlocked the door. Walton licensed the technology to lock makers and other similar companies.

The testing of these technologies was still relevant when one of the authors worked for United Parcel Services (UPS) in the early 1990's in the Strategic Systems Group. Unfortunately, the reliability and the cost effectiveness were not viable even 20 years later at a company as successful as UPS.

13.3.13 Toll Road and Animal Tracking

Also in the 1970s, Los Alamos National Laboratory at the request of the United States Energy Department developed a system for tracking nuclear materials. Scientists developed the idea of putting a transponder in a truck and readers at the gates of secure facilities. The gate's antenna would wake up the transponder in the truck, which would respond with an ID and potentially other data, such as the driver's ID then the gate would automatically open.

There was a realization on how RFID technologies specifically electronic vehicle identification could change transportation. This was evidenced in the transportation efforts including work at Los Alamos and by the International Bridge and Turnpike and Tunnel Association (IBTTA) and the U.S. Federal Highway Administration. Unfortunately, the IBTTA and U.S. Federal Highway Administration held a conference in 1973 and concluded that there is no national interest in developing a standard for electronic vehicle identification. The late 1970s is when companies realized the potential commercial aspects of RFID, companies such as Identronix a spin-off from Los Alamos Scientific Lab, Amtech, who later became part of Intermec and Transcore were developed.

Later in the mid-1980s, this type of system was commercialized when former Los Alamos scientists left and formed companies which developed automated toll payment systems. These systems have become widely used on roads, bridges, and tunnels around the world. Organizations such as the Port Authority of New York and New Jersey tested electronic toll collection systems built by General Electric, Westinghouse, Philips, and Glenayre.

Also in the 1970's, animal tracking efforts were initially investigated using microwave systems at Los Alamos and using inductive technologies in Europe. Animal ID was pursued in Europe by Alfa Laval, Nedeap, and others.

Other forward moving occurrences in the 1970's included the use of modulated backscatter. In 1975, Alfred Koelle, Steven Depp, and Robert Freyman introduced the transcript "Short-range radio-telemetry for electronic identification using modulated backscatter", which is the foundation for current RFID passive tags. Other events include the development of the Raytheon's "Raytag" along with other events from Radio Corporation of America (RCA) and Fairchild in RFID development. Richard Klensch of RCA developed the "Electronic identification system" in 1975, and Sterzer of RCA developed an "Electronic license plate for motor vehicles" in 1977. Thomas Meyers and Ashley Leigh of the Fairchild organization developed "Passive encoding microwave transponder" in 1978.

In the 1980s, RFID history documents many commercial implementations. The most common implementations in the United States were for transportation, personnel, and animals. In Europe, interests were in short-range systems for animals and industrial and business applications. Toll roads in Italy, France, Spain, Portugal, and Norway were equipped with RFID. The USA Association of American Railroads and the Container Handling Cooperative Program were active with RFID initiatives. Though testing of RFID for collecting tolls had been going on for many years, the first commercial application began in Europe in 1987 in Norway. This was followed quickly in the United States by the Dallas North Turnpike in 1989. Port Authority of New York and New Jersey began commercial operation of RFID for buses going through the Lincoln Tunnel. RFID was finding a home with electronic toll collection.

Also Los Alamos was requested by the Agricultural Department to develop passive RFID tags to track cows. The goal was to facilitate the tracking of the amount of hormones and medicines that were administered to cows when they were ill. The challenge of ensuring that each cow received the correct dosage was having multiple economic factors. Los Alamos came up with a passive RFID system that used 125 kHz radio waves. A transponder encapsulated in glass is injected under the cow's skin or is attached to an identification tag. The transponder draws energy from the reader and reflects back a modulated signal to the reader using a technique known as backscatter. This system is still used in cows around the world today.

These low-frequency transponders were also put in cards and used to control the access to buildings.

Over time, companies commercialized 125 kHz systems. Later other companies developed systems that operate on higher radio spectrum to high frequency (13.56 MHz). This frequency was chosen because it was unregulated and unused in most parts of the world. This frequency offered greater range and faster data transfer rates. Companies in Europe began using it to track reusable containers and other assets. The 13.56 MHz frequency RFID systems are used for access control, payment systems (Mobile Speed pass), contactless smart cards, and as an anti-theft device in cars. The cars have a reader in the steering column that reads the passive RFID tag in the plastic housing around the key. The car is rendered disabled if the ID number it is programmed to look for is not found.

In the early 1990s, IBM engineers developed and patented an ultra-high-frequency (UHF) RFID system which offers longer read ranges—20 ft under good conditions and faster data transfer. IBM did some early pilots with Wal-Mart but never commercialized this technology, but IBM ran into financial trouble in the mid-1990s and sold its patents to Intermec, a material handling systems provider. Intermec has been installed in numerous different applications, from warehouse tracking to farming. Intermec invested in this future technology due to the fact that at the time it was expensive because of the low volume of sales and lack of international standards.

Also in 1990s, electronic toll collection using RFID technologies expanded to wide-scale deployment of electronic toll collection in the United States. Open highway electronic tolling system opened in Oklahoma in 1991 in which cars pass scanning points at highway speeds (no need for cameras or barriers). The world's first combined toll collection and traffic management system was installed in the

Houston area by the Harris County Toll Road Authority in 1992. Both of the authors personally were able to witness the construction of the toll road in Houston.

Later, the Kansas turnpike used a system based on the Title 21 Standard which allows usage by other states such as Georgia who also used the same standard. The Title 21 Standard was designed to have a multi-protocol capability in electronic toll collection applications. Also, in the Northeastern United States, seven regional toll agencies formed the E-Z Pass Interagency Group (IAG) in 1990 to develop a regionally compatible electronic toll collection system. Also, toll tags were integrated for multi-use applications in parking garages, toll booths, gated communities, and business campuses; an example would be the Dallas TollTag.

The development of computer engineering technology which allowed microwave Schottky diodes fabricated on a regular Complementary metal–oxide–semiconductor (CMOS) integrated circuit permitted the construction of the microwave RFID tags. These tags contained a single circuit, which previously had been limited to inductively coupled RFID transponders, thus allowing for cheaper active tags and readers.

Federal Communications Commission (FCC) allocated a spectrum in 5.9 GHz band for expansion of intelligent transportation systems, which will spur more RFID development and applications. RFID systems have been installed in numerous different applications, from warehouse tracking to farming. But the technology was expensive at the time due to the low volume of sales and the lack of open, international standards.

13.3.14 Development of Cost-Effective Protocol

In early 1999, when the Uniform Code Council (UCC), EAN International, Proctor & Gamble, and Gillette established the AutoID center at the Massachusetts Institute of Technology (MIT). Two research professors, David Brock and Sanjay Sarma, initiated the idea of integrating low-cost RFID tags on to products in order to track them through the SC. Their idea of transmitting a unique number from the RFID tag in order to keep the cost of the technology cost effective was novel. The idea of using a simple microchip that stored very little information as opposed to using a more complex chip that may require batteries and require more memory allowed for the cost-effective implementation of the idea. Data associated with the serial number on the tag would be stored in a database that would be accessible over the Internet.

Sarma and Brock changed the way people used RFID in the SC. Previously, RFID tags were considered mobile databases that contained information about the product, case, pallet, or container on which they were attached. Sarma and Brock promoted the idea of RFID as an associating networking technology that linked objects to databases through the Internet through the tag. This was an important change to businesses because this enabled the idea of visibility. For example, a manufacturer could automatically let a business partner know when a shipment was leaving the dock at a manufacturing facility or warehouse, and a retailer could automatically let the manufacturer know when the goods arrived.

Between 1999 and 2003, the AutoID center gained industry acceptance of the passive RFID tagging system with the support of more than 100 large end-user companies, the U.S. Department of Defense, and RFID vendors. AutoID research labs were opened in Australia, the United Kingdom, Switzerland, Japan, and China. The AutoID center is credited with developing two air interface protocols (Class 1 and Class 0), the EPC numbering scheme, and a network architecture for associating data on an RFID tag. The technology was licensed to the UCC in 2003. The UCC created EPCglobal organization as a joint venture between the AutoID center and EAN International in order to commercialize EPC technology. The AutoID center closed its doors in October 2003, and its research responsibilities were passed on to AutoID labs.

The industry support is evidenced in the fact that some of the biggest retailers in the world—Albertsons, Metro, Target, Tesco, Wal-Mart—and the U.S. Department of Defense have initiated plans to use EPC technology to track goods in their SC. The pharmaceutical, tire, defense, and other industries are also moving to adopt the technology. EPCglobal ratified a second-generation standard in December 2004 in order to compensate for some of the shortcomings of the first-generation technologies improving challenges such as read distance and better integration between vendor products.

13.3.15 Overview of Passive and Active RFID Technologies

An RFID system consists of a reader, tags, and an air interface. The reader, also known as an interrogator, sends out a signal through an antenna. This signal is usually in the form of an electromagnetic wave. Because the signal is in the form of an electromagnetic wave, a direct line of sight is not needed to read the information on the tag. This is a major advantage of RFID. The signal is received by the tag, and a response signal is sent back to the reader. This response signal contains a unique identifier associated with tag. The response signal can be powered in two ways corresponding to the type of tag. Passive tags utilize the energy of the original signal to send a response signal back to the reader. Passive tags have a limited amount of energy to power the response signal. Therefore, the amount of information transmitted by a passive tag is fairly small: quite similar to the information carried in a barcode.

Active and semi-active tags use energy from an attached battery to power the response signal. The use of the embedded battery allows the response signal to contain more information and travel farther. The reader receives the response signal, decodes it, and sends that information to a database. Often the information in the response signal is connected to additional information in the database.

RFID technology can be used throughout the SC in order to promote visibility. This visibility helps coordinate actions between entities in the SC. Figure 13.2 shows the relationships within the SC that can be affected by the implementation of the RFID technologies. An example of RFID implementation is the use of active tags for detecting tampering and monitoring security of maritime containers. Those types of tags also have the tracking advantages of RFID and can be used to improve operations management.

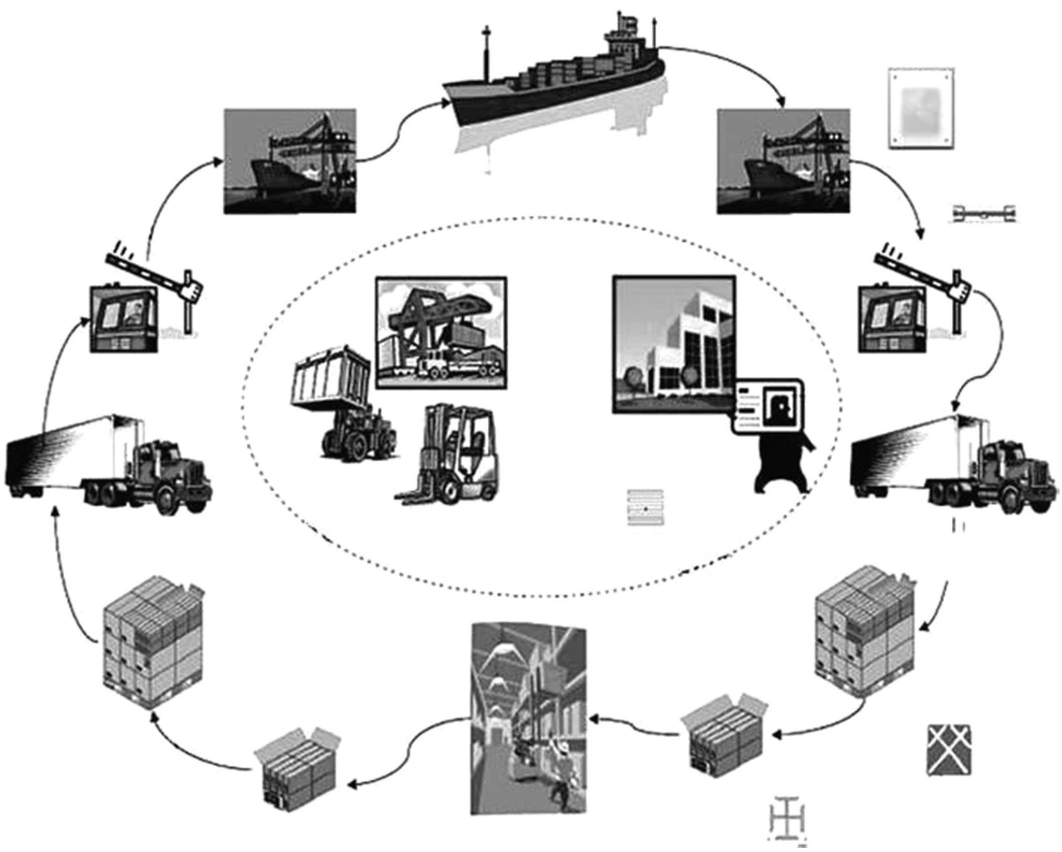

FIGURE 13.2 Integrated supply chain with RFID.

13.4 Global Positioning System

The Navistar Global Positioning System also referred to as GPS has three components:

1. A constellation of satellites orbiting approximately 20,000 km above the earth.
   There are approximately 27 satellites transmitting ranging signals on frequencies in the microwave ranges in the radio spectrum. The transmission frequencies range from 1 to 10 GHz. Most point-to-point services offered today use the frequency bandwidths of (1) 5.92–6.425 GHz for transmission from earth to satellite called uplink, (2) 3.7–4.2 GHz for transmission from satellite to earth called downlink.
2. Ground control monitor stations which control uplink to the satellites.
3. Receivers for the users. There are both Civil and Military users.

In general, the GPS consists of a series of satellites orbiting the Earth and receivers. GPS works by calculating the distances from a receiver to a number of satellites. With each distance between a receiver and satellite, the number of possible locations is narrowed down, until there is only one possible location. A receiver must calculate its distance from at least three satellites to determine a location on the surface of the Earth. However, four satellites are usually used to increase the location accuracy. This process of location would be controlled by the positioning module of GPS. A GPS positioning and navigation system has the following modules:

- Digital Map Database
- Map Matching
- Route Planning and Guidance
- Human–Machine Interface
- Wireless Communication.

There are three positioning technologies that can be used: radio wave-based positioning, dead reckoning, and signpost. The use of GPS for navigation can have direct and indirect impacts on Intelligent Transportation Systems. GPS navigation systems can provide information about local surroundings. Also, emergency personnel can be provided with a precise location for situations, thus reducing response times. Asset tracking is one of the most popular uses of GPS. One of the limitations of GPS is that receivers cannot communicate with satellites when indoors.

13.4.1 Integration of Real-Time Technologies and GPS

RFID and GPS are emerging technologies that will allow for real-time data collection to assist with decision support in supply chain management (SCM). RFID has a wide variety of applications. Some examples of RFID uses are library checkout stations, automatic car toll tags, animal identification tags, and inventory systems. Real-time data collected using RFID allows an SC to synchronize reorder points and other data. Real-time information can also be used to design and operate logistical systems on a real-time basis. GPS is currently used solely as a means to locate equipment and derive navigation directions.

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- Digital Map Database
- Map Matching
- Route Planning and Guidance
- Human–Machine Interface
- Wireless Communication.

There are three positioning technologies that can be used: radio wave-based positioning, dead reckoning, and signpost. The use of GPS for navigation can have direct and indirect impacts on Intelligent Transportation Systems. GPS navigation systems can provide information about local surroundings. Also, emergency personnel can be provided with a precise location for situations, thus reducing response times. Asset tracking is one of the most popular uses of GPS. One of the limitations of GPS is that receivers cannot communicate with satellites when indoors.

RFID and GPS are radio wave-based technologies that are currently used by many organizations. RFID is primarily used in inventory and material handling processes. Tags are placed on items. When these items pass by checkpoints where readers are located, the tag is read, and the appropriate action can be taken. Real-time inventory can be kept by monitoring tag reads at strategic points like loading docks. RFID can also be useful in material handling. Items on a conveyor can be diverted at the appropriate times based on the information received from the RFID tag. GPS is primarily used to track assets such as vehicles and other expensive equipment. For example, if a truck breaks down, it is possible to locate the truck and get the shipment moving again in the fraction of the time it would take with a GPS receiver.

Current applications of RFID and GPS systems have allowed for more effective tracking of inventory and assets. These technologies can be used in conjunction, but the data has to be captured and written to a database to be correlated to other tags or receivers. If these technologies can be combined to produce hybrid systems, greater gains can be achieved. One focus of research is the nesting of GPS receivers and various RFID tag types. If tags and receivers were able to communicate with one another, even more accurate real-time data collection could be achieved during transportation. This would also reduce equipment costs, because fewer readers would be required.

If these technologies can be nested, it would allow the information in a barcode or a passive RFID tag to be collected by an active tag. This information could then be combined with the information contained within the active tag and transferred to a GPS receiver. The GPS receiver could then send not only its location but all of the information about the cargo being shipped. A possible application of this nested technology approach would be in the railroad industry. Currently, there two passive RFID tags attached to the sides of all rail cars in the United States. In addition, most railroads are using GPS receivers to track locomotives. If nesting became possible, implementation would be easy in this case. Active tags could be used to capture the information correlated to the cargo in all of the rail cars and transmit it to the GPS receiver and thus to the inventory databases.

In addition to nesting technologies, more advanced tags can be developed to allow more detailed data collection. Tags that utilize sensors to capture and write data to the tag are being developed. Some tags have been developed but are still very unreliable. These sensor tags could be used to monitor physical parameters, like temperature and humidity, as well as security parameters. The main problem faced by these passive sensor tags is the limited power supply. The sensor cannot use any energy while outside the range of the reader. Also, the amount of energy available while in read range is very small. This limits possible measurement techniques. With these sensor tags, perishable goods could be monitored to guard against possible safety issues. This could include salmonella outbreaks caused by frozen chicken reaching too high of temperatures for too long and medications being held at temperatures that reduce potency.

13.4.2 Conclusion

Technologies are being used to allow real-time data collection. This allows for more dynamic SCM systems that are able to adjust to varying market and environmental conditions. RFID and GPS facilitate this dynamic SCM. RFID allows for up-to-date inventory levels and, when combined with GPS, can provide a means of tracking inventory as it moves from supplier to customer through the SC. New technologies are being developed to further the amount of information to decision support systems for SCM.

13.5 RTLS

Current RTLSs are typically active systems (using battery-operated tags) to detect presence and location within a 2D coordinate system (XY position only, not height). The license-free frequency ranges are most popular (300–433 MHz) and in particular the 2.45 GHz. At this frequency range, time of flight is efficient, and many RTLSs are based on WiFi, Bluetooth, or Zigbee which occupy this frequency band. Most or all of these current RTLSs rely on the signal strength as an indicator for distance approximation. Other systems use active RFID, infrared, ultrasound, ultra wide band (UWB), or a combination of them to perform the localization.

Below are a subset of the RTLSs that are generally based on the aforementioned procedure.

13.5.1 WiFi RTLS

The Ekahau company is currently incorporating an RTLS using an existing WiFi (802.11) network. The system works by using Received Signal Strength Indicator (RSSI) between multiple access points throughout the tracking area. This provides accuracy indoors of 3–9 ft. The system does not cause any interference to the existing network traffic because the tag communicates only about 60 bytes of data per location update. The tags are active and require a 4–6 V power source. The tags have built in accelerometers and can be configured to report location any time it is moved. Many other companies have previously employed versions of a WiFi RTLS system into operations which has created a great amount of interest due to the fact that these location systems can be incorporated into existing networks.

13.5.2 Active RFID RTLS

RF code has combined active RFID and infrared (IR) in an RTLS implementation.

The system has a read range of up to 10 m.

13.5.2.1 UWB

Multispectral Solutions, Inc. incorporated UWB into an RTLS system based on triangulation ranging. These active tags use time of flight measurements and can achieve location accuracy within 10–30 cm. The read ranges are also around 200 m (Line of Sight (LOS) and about 50 m indoors through obstructions.

13.5.3 Passive RFID RTLS

An approach was used which was able to achieve an accuracy of 0.6 m using a Bayesian statistical method on readings collected from multiple RFID readers. This was accomplished without exploiting any prior information about the location, orientation, or power delivered to the tag.

13.6 Differences in Using RFID, RTLS, and GPS

RFID and GPS are radio wave-based technologies that are currently used by many organizations. RFID is primarily used in inventory and material handling processes. Tags are placed on items. When these items pass by checkpoints where readers are located, the tag is read, and the appropriate action can be taken. Real-time inventory can be kept by monitoring tag reads at strategic points like loading docks. RFID can also be useful in material handling. Items on a conveyor can be diverted at the appropriate times based on the information received from the RFID tag.

RTLS is generally considered similar to GPS or vice versa in that they both use localization algorithms to triangulate positions. Technically GPS can be considered a satellite-based RTLS. The main difference for non-satellite-based RTLSs is that they mainly operate indoors. On the contrary, GPS is traditionally used for outside position location. Also, some RTLSs are considered more accurate than GPS in outdoor conditions, but the main limitation is the need for infrastructure.

GPS is primarily used to track assets such as vehicles and other expensive equipment. For example, if a truck breaks down, it is possible to locate the truck and get the shipment moving again in the fraction of the time it would take without a GPS receiver.

13.6.1 Trend to Integrated AIT Applications

Recently, there has been some confusion by SC managers between the objectives for using RFID technologies and GPS. To add to the confusion, the marketing of the technologies by different vendors has made it difficult for many organizations to decide which technology is best for their operations. Though each technology has different operational objectives, the association of these technologies as ADC technologies have led many to believe the benefits of the technologies are interchangeable. Recently, some manufacturers have created technologies that have integrated both technologies so that their benefits can be leveraged.

Current applications of RFID and GPS systems have allowed for more effective tracking of inventory and assets. These technologies can be used in conjunction, but the data has to be captured and written to a database to be correlated to other tags or receivers. If these technologies can be combined to produce hybrid systems, greater gains can be achieved.

One focus of research is the nesting of GPS receivers and various RFID tag types. If tags and receivers were able to communicate with one another, even more accurate real-time data collection could be achieved during transportation. This would also reduce equipment costs, because fewer readers would be required. The concept of requirement layers for determining the required technology is demonstrated in Figure 13.2. These layers were developed by Bob Kenney at SAVi Technologies (Lockheed Martin) and based off of the following ideas:

- ISO has grouped SC goods into logistic unit hierarchy.
- Objects in each layer are handled differently and have different requirements for each part of the SC.
- Necessitates different requirements for each layer.

If these technologies can be nested, it would allow the information in a barcode or a passive RFID tag to be collected by an active tag. This information could then be combined with the information contained within the active tag and transferred to a GPS receiver. The GPS receiver could then send not only its location but all of the information about the cargo being shipped. This concept was demonstrated earlier and shown in Figure 13.2.

A possible application of this nested technology approach would be in the railroad industry. Currently, there are two passive RFID tags attached to the sides of all rail cars in the United States. In addition, most railroads are using GPS receivers to track locomotives. If nesting became possible, implementation would be easy in this case. Active tags could be used to capture the information correlated to the cargo in all of the rail cars and transmit it to the GPS receiver and thus to the inventory databases.

An application that has recently been developed is demonstrated by the Dow and Chemtrec Company. This application was created to incorporate a tag that uses GPS, RFID, and sensors to track hazardous materials on railcars. The goal of the application was for constant monitoring of hazardous material conditions for railcars. The technology was based on RFID tags required by the American Association of Railroad RFID initiative (Automatic Equipment Identification (AEI)) since the 1970s.

In addition to nesting technologies, more advanced tags can be developed to allow more detailed data collection. Tags that utilize sensors to capture and write data to the tag are being developed. Some tags have been developed but are still very unreliable. These sensor tags could be used to monitor physical parameters, like temperature and humidity, as well as security parameters. The main problem faced by these passive sensor tags is the limited power supply. The sensor cannot use any energy while outside the range of the reader. Also, the amount of energy available while in read range is very small. This limits possible measurement techniques. With these sensor tags, perishable goods could be monitored to guard against possible safety issues. This could include salmonella outbreaks caused by frozen chicken reaching too high of temperatures for too long and medications being held at temperatures that reduce potency.

An example of a tag that captures sensor data and transmits using GPS technologies is the Hammer tag system. This system provides for the creation of a Personal Digital Assistant (PDA) that can write both image and geospatial location data to active RFID tags that can be later captured and integrated into a geographical information system (GIS). The main use was to capture information for geological digs.

Other applications include nesting the RFID and GPS technologies for use with maritime container applications to offset the shortcomings of the different technologies.

The combination of GPS and active RFID tags on marine cargo containers allows for location of maritime containers using RFID-based RTLS that utilizes wireless access points. In the event the RFID wireless access points are not available, the device switches to a GPS-based RTLS. This system design was created to improve the challenges and system limitations of the RFID RTLS system that are caused by the operational conditions of marine ports.

Other scenarios for this type of nesting technologies include military use.

A satellite-based RFID service is described by an OrbitOne application. This GPS tag utilizes a battery powered active RFID tag to capture information at predetermined times in challenging military environments. The information capture through RFID interrogation is later transmitted via LEO (low earth orbit)-based satellites.

Another application utilizes the nesting concept of RFID, GPMS, and GPS for tracking gas distribution in gas tankers. This RFID-based system creates a device which contains an active RFID reader that captures active tag information from tanker gas valves. As the gas valve is opened, the active tag associated with the valve transmits a signal to the active RFID tag reader or interrogator. Later the RFID tag reader transmits information to a general packet radio service (GPRS) connection located in a computer system on-board the tanker's trailer cab. Finally, this GPRS transmits information to operations through a GPS. Another example of this nested GPS and active RFID system includes the Unipart system which is used for traditional SC operations as a means to tracking inventory on tractor trailers.

13.6.2 Summary

Technologies are being used to allow real-time data collection. This allows for more dynamic SCM systems that are able to adjust to varying market and environmental conditions. RFID and GPS facilitate this dynamic SCM. RFID allows for up-to-date inventory levels and, when combined with GPS, can provide a means of tracking inventory as it moves from supplier to customer through the SC. New technologies are being developed to further the amount of information to decision support systems for SCM.

Some technologies can be used to make real-time adjustments to the SC. Those adjustments could be due to many events such as manpower shortages or equipment breakdowns. For example, if a problem occurs to a truck or the road conditions change due to weather, the system, supplied with this updated information, should be able to make the necessary corrections to the transportation routes of other trucks to compensate for the truck failure. This system would be very useful during natural disasters.

With real-time information, the system would reallocate transportation and production to a place that would be the optimum solution. This kind of modeling would reduce the response time for such events from months or weeks to days or hours. This system can also be expanded to urban transportation within a city or long distances.

13.7 Automation in Warehousing

13.7.1 Introduction

It is important to discuss software when we describe RFID and operations such as warehousing. Since the mid-1990s, warehousing and other operations have become computerized. To realize any benefit from technologies such as RFID, operations must be computerized. In this section, we describe the different types of systems that allow for efficient operations. Because software and middleware are the most important pieces of an RFID solution, these packages are needed to make use of information collected by RFID technology with all the other systems operating in the warehouse: warehouse management systems (WMSs), transportation management systems (TMSs), event management systems, order management systems (OMSs), and enterprise resource planning (ERP) systems.

The ability to capture, store, rationalize, and integrate information captured by RFID technology, including product information, location, volume, and transactional data, allows organizations to more efficiently pick/pack, ship, route, track, and distribute materials. This operational improvement can result in lower inventory levels and improved labor and equipment productivity. Integrating the information from RFID tags into an ERP system allows alerts to be sent that pre-set conditions have occurred such as inventory max–min levels have been realized. System standards and compatibility problems can result in expensive software implementation process. Standards are currently being developed at EPCglobal.

13.7.2 Warehouse Applications

Manhattan Associates, the largest WMS vendor, has built its business by implementing software that allows for warehousing best practices. Bobby Collins, Senior Vice President (SVP) of national accounts, suggests that the warehousing problems drive efficiencies and costs in most large and small companies. He describes that WMS implementations seek to drive value by solving the warehousing problems. The top ten warehousing problems are as follows:

- Inventory accuracy
- Space utilization
- Picking information
- Slotting
- Order picking
- Order accuracy
- Returns
- Vendor coordination
- Performance reporting
- Strategic planning.

Warehousing is a requirement of a successful business. Warehousing delivers customer satisfaction. When implementing WMSs, a standard implementation process includes the following master planning methodology:

- Document current warehouse operations
- Determine future requirements over the planning horizon

- Identify and document deficiencies in the existing warehouse
- Identify and document alternative warehouse plans
- Qualitative and quantitative evaluation of alternatives
- Select and specify a plan
- Detail planning
- Implementation.

In the following sections, we provide a brief overview of relevant warehousing operations and how RFID may support improvements in these areas. Also in the text, there is an overall presentation of warehousing and WMS donated by Global Concepts on best practices for warehousing and WMS to further describe usage improving warehousing operations.

13.7.3 Receiving

RFID technology eliminates the need to physically check the bill of lading and/or the packing slip during the receiving process in a warehouse. This represents a significant labor reduction and inventory accuracy improvement in most operations. RFID can alert most WMSs to indicate if a product needs a cross-dock movement. Cross-docking is the process in which product received can be identified as an immediate need to fulfill an order and is immediately loaded into outbound trailers to fulfill the order. This cross-docking process reduces the labor and time to store, replenish, pick, pack, and ship a product. The system requirement consists of a WMS interfacing with an OMS to determine if this product is needed so that a task can be created to ship the product "across the dock" to the outbound dock so the order can be completed and placed on the waiting vehicle. RFID makes the identification of these types of immediate need orders easy and possible more reliably than traditional barcode scanning.

If using a conveyor receiving process or conveyor in general, RFID provides greater efficiencies by eliminating the need to ensure that cases/items are placed properly on the conveyor so that the barcode can be read accurately. RFID allows for accurate reads regardless of product position, resulting in fewer reading errors.

13.7.4 Storage

RFID system can eliminate the need to scan the barcode on the pallet and at the storage, replenishment, and picking locations for the different types of storage racks. RFID scanners can continuously scan locations using WMS specification and create task from identification of inventory inaccuracies. Since the RFID tags can be read from anywhere, products and pallets do not have to be placed in specific or assigned locations such as the golden zone illustrated in Figure 13.3. Material handling principles such as using random storage locations system, minimizing honeycombing, and replenishing to fast picking zones can be realized.

13.7.5 Pick/Pack

RFID readers can be integrated with the WMS to validate that the correct items and amounts are picked and measure productivity in the warehouse.

13.7.6 Shipping

An RFID reader can confirm that each item is placed onto the correct outbound vehicle, which can improve the accuracy of the shipping process. This verification can be made as the product moves through the portal to the outbound dock door. RFID allows for an automatic check of the items loaded into the trailer against the bill of lading. Using RFID readers or portals at exits of the facility and employee areas ensures that all items leaving the building are accounted for.

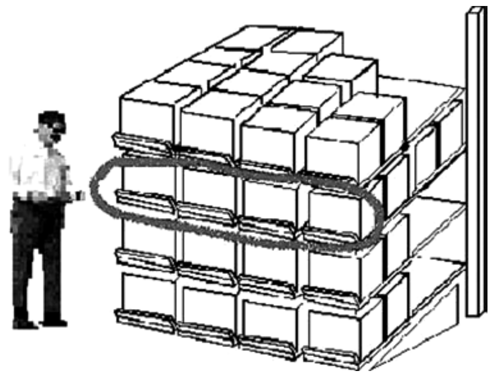

FIGURE 13.3 Golden zone concept.

13.7.7 Reliability

The reliability of the RFID tags is a problem with many pilot implementations. Currently, RFID accuracy for Walmart implementations has averaged between 70% and 75%. General problems including problems with accuracy are related to multiple reads and no reads because of readers inadvertently scanning adjacent products and/or double scanning the same product. Others include products containing metal or liquids that will reflect, respectively, the signal from the RFID scanner. Metal racking systems could also pose a problem of reflected signals. Additional problems occur with data overload from the high-speed movements of products. "No reads" create a unique problem or RFID technology at the present. With barcode technology, the reader can detect if it did not read a barcode. With RFID technology, a "no read" goes undetected.

13.7.8 IT Infrastructure Issues

One of the major concerns is the potential bandwidth requirement or an RFID system capturing all the available data from every RFID tag in a given warehouse. The potential volume of information from real-time scans moving between multiple applications or every single case or pallet in a warehouse can easily overwhelm even the most robust information system. Hewlett Packard uses RFID in its facilities in Memphis, Tennessee; Chester, Virginia; and Sao Paulo, Brazil. These sites generate 1–5 TB of data a day. Therefore, organizations must analyze the potential data from an RFID tag and determine what information needs to be captured in real time and what information can wait for a batch update. The information systems also need to be robust enough to handle the speed increases associated with a successful RFID implementation. Shorter scanning intervals, faster product movements, and shorter order cycle times must be handled without sacrificing system integrity.

Other problems include the differences between storing UPC barcodes, which are 11 digits, and storing RFID serial numbers, or EPCs, which are 13 digits. The UCC, a standards body for the retail and manufacturing industries, states that their Sunrise 2005 initiative requires all U.S. and Canadian companies to be capable of scanning and processing up to 14-digit barcodes by January 2005.

Slap and ship RFID implementation approach requires a minimal amount of investment to slap tags onto a subset of outgoing shipments to comply with the current mandates. The second approach relies on larger investments to develop an internal capacity that impacts the SC upstream, in an effort to both comply with mandates and capture operational efficiencies from RFID.

The slap and ship approach is driven by the mentality that RFID is a cost of doing business due to the mandates set forth by both Walmart and the US Department of Defense (DoD). Organizations employing this strategy are not looking for a short- or long-term Return on Failure (ROF) on their investment; they are only concerned with being compliant with their customers so that they are able to continue doing business. This approach oftentimes is just as costly as a well-thought-out long-term strategy to use the technology. Most pundits suggest that the second approach should be utilized in order to increase business efficiency. The next section provides some implementation examples in which the companies sought to integrate RFID into operations.

13.7.9 RFID Warehouse Implementation Examples

The following are examples of RFID system implementations in various companies in different business sectors.

13.7.9.1 Gillette

In January 2003, Gillette bought 500 million Class I EPC tags from Alien Technology. Gillette has been using the order to tag all pallets and cases of women razors. Gillette worked with its WMS and TMS provider, Provia, to ensure that the RFID information can be integrated into the appropriate systems. Below is an explanation of how Gillette has incorporated the tags into their processes.

13.7.9.2 International Paper

International Paper, the world's largest paper and forest products company, went live with their first fully automated RFID warehouse tracking system in August 2003. The use of truck-mounted RFID readers and proprietary tracking technology provides forklift operators with execution task information. The elimination RFID portals in tracking inventory movement for the use of mobile forklifts truly integrating RFID in operations have provided more efficiency.

13.7.9.3 Proctor & Gamble

Proctor & Gamble performed a pilot project in which they used RFID at an international manufacturing plant in Spain to send pallets to domestic operations. Results indicated this was a cost-effective way to implement RFID tagging.

Case Study

RELATED BACKGROUND TO ADC, RFID, MILITARY, OR LOGISTICS

Military logisticians can use RFID technology to track troop movement as they use different modes of transportation. For example, they may use a bus to get to the military base, a carrier to get to the next port, a train in an international country, and possibly a tank as they are in theater. We look at a simple example of how one public transportation agency uses RFID technology to support data analysis of passenger demand.

In 2008, gas prices peaked, and Metropolitan Transit saw a record increase in the number of passengers it served. To avoid spending a small fortune on gas, local residents began to take the train for their daily commute to work. Over the past year, passenger use of the trains has fluctuated with gas prices and economic conditions. Methods for tracking passenger counts have been manual, leaving room for error. Variability in passenger usage has made it more difficult to determine if the variability in count was due to an error or due to actual changes in usage. In addition, Metropolitan Transit is facing its own budget cuts and is looking at potentially reducing the number of trains it runs.

To more accurately provide trains based on passenger demand, Metropolitan Transit has launched a new fare collection system that uses smart card technology to collect data as passengers enter and exit the train station. With the new fare collection system up and running, Metropolitan Transit is ready to begin analyzing passenger demand.

Prior to boarding a train, passengers can load a one-way or round-trip fare onto a plastic card that looks similar to a credit card but has an embedded RFID microchip. To enter and exit the train station, passengers tap the card to a card reader that records the station location, time of day, and type of fare loaded on the card.

METHODS AND RELATED MODELS

The data set for the first month of operations since the launch of the new smart card system has been collected and is ready for analysis. The passenger demand, D, followed a uniform distribution $D_{\min}$ = 200 and $D_{\max}$ = 400. The supply of trains can now be calculated with the Newsvendor model by using the number of passenger seats to determine the number of trains needed. Each train has 50 seats. The optimal quantity, q, using the newsvendor model is

$$q = F^{-1}\left(\frac{p-c}{p}\right),$$

where F^{-1} is the inverse cumulative distribution function of D, with price, p, and cost, c.

SAMPLE PROBLEM

Metropolitan Transit assumes that there is a cost, c, and a price, p, for each seat on the train. Assume that the price is the passenger fare for one trip: $p = 2$ [$/passenger seat] and the cost of each seat on a train running along the route is $c = 1$ [$/passenger seat]. The optimal quantity of passenger seats is calculated as

$$q_{\text{opt}} = F^{-1}\left(\frac{2-1}{2}\right) = F^{-1}(0.5) = D_{\min} + (D_{\max} - D_{\min}) * 0.5 = 300$$

Therefore, the optimal number of trains that Metropolitan Transit should send out is six trains.

CONCLUSION

RFID technology provides a method to more accurately gather data on how passengers interact with a system. As passengers register their smart cards with identifying information, Metropolitan Transit can also adjust other components of its transportation system as passengers move from train to bus to commuter bus.