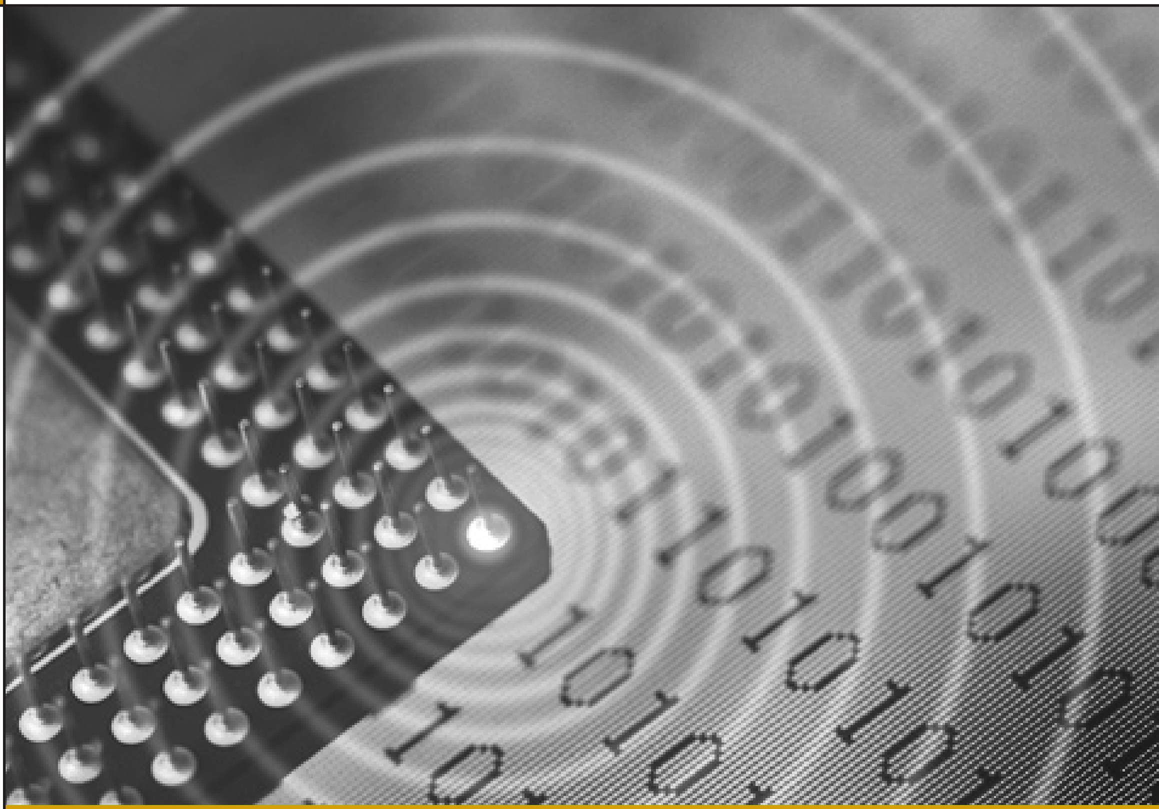
OCTOBER 2005

RFID: The Right Frequency for Government



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E–Government Series

IBM Center for
The Business of Government

E–GOVERNMENT SERIES

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IBM Center for
**The Business
of Government**

TABLE OF CONTENTS

FOREWORD

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On behalf of the IBM Center for The Business of Government, we are pleased to present this report, "RFID: The Right Frequency for Government," by David C. Wyld.

The evolution and application of new technologies have been at the forefront of allowing the United States and other countries to improve the quality of life and increase standards of living. Radio frequency identification (RFID) is another such application—an enabling technology that, we believe, will have a substantial impact over the next two decades.

Professor Wyld's report, his fourth for the IBM Center for The Business of Government, provides an important contribution to the literature around RFID by chronicling its history and setting out the opportunities that it provides, especially for the public sector. The bar code, a previous identification technology advance, has had a significant impact during the past 30 years. Now, with the emergence of RFID technology, new opportunities will arise and its impact will continue to grow as new applications are realized. In addition, we expect the time to reach significant impact will be half of what it was for bar-code technology.

The integration of RFID technology with other information technology makes a paradigm shift now possible. RFID technology can track patient safety by error-proofing processes for medication, as well as providing global visibility of worldwide shipments, which will improve the flow of commerce and the security of nations. The future role of RFID will dramatically increase its impact over that of its predecessors.

The potential of RFID is indeed great. The supply chain management industry refers to the "three V's of RFID": visibility, velocity, and value. RFID promises to increase visibility to make earlier and better decisions and actions possible. Second, RFID will enable the flow of goods and information to be accelerated, with a higher certainty of information for decision making. Finally, RFID will enable important enhancement of value, often in new ways. As described by Professor Wyld, RFID offers the potential to provide increased safety for patients, faster movement of automobiles from manufacturer to dealer, and greater national security.

We trust that Professor Wyld's report will make a valuable contribution to the understanding of the potential of RFID and how it might be applied in the public, private, and nonprofit sectors.

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EXECUTIVE SUMMARY

We are in the midst of what may become one of the true technological transformations of our time. RFID—radio frequency identification—is by no means a new technology. In fact, it dates back to the techniques developed to differentiate "friendly" aircraft from enemy warplanes in World War II. However, significant improvements in functionality; decreases in both size and costs, especially in the last decade; and agreements on communication standards have combined to make the technology viable for commercial purposes. Now American ingenuity and vision have positioned RFID as an alternative way to identify "things" to the omnipresent bar code. In doing so, whole new ways of doing things, of managing the supply chain, and of interacting with objects are being made possible through the creation of "an Internet of artifacts." With the projected rapid rise of RFID over the next decade, new markets and new opportunities will be created through what futurist Paul Saffo has labeled a "weird new media revolution."

This report provides the reader with an overview of RFID technology. It begins with a discussion of the power of identification, and a delineation of the power RFID has over bar codes as an identifier of unique items, rather than simply being a categorical label. Then, what is a short course in "RFID 101" is provided, so as to equip the non-technical reader with a functional understanding of how the technology operates with RFID-tagged or -labeled items and RFID readers. We discuss the radio frequencies used for RFID systems, when to use each, and the challenges involved in making the component parts of RFID work together effectively to produce the speedy and accurate recognition of objects that is the promise of automatic identification technology. Leading organizations, such as the U.S. Department of Defense, and retailers like Wal-Mart and Target, have set stretch goals for their suppliers to begin using RFID on shipments to their organizations. In the next section of the report, we appraise the "informationalized" supply chain and what this increased visibility will mean for both procuring organizations and their suppliers. Despite the present uncertainties over data management and return on investment issues, many agree with Harris Miller, president of the Information Technology Association of America, who commented that "near-term obstacles aside, RFID will clearly become the heart of inventory and supply chain management technology for large enterprises of all kinds, including government agencies" (opinion cited in Anonymous, "Study Finds Government Application of RFID Technology at the Crossroads," 2004, n.p.).

Much of the focus in the media and the marketplace has been on the many private sector RFID initiatives. However, the public sector has been an extremely active area of RFID activity in three very different, very prominent supply chains. In this report, we present three case studies of RFID's application in supply chain management:

1. The Department of Defense's supply chain mandate, which is seeking to integrate RFID in the world's largest and longest supply chain.
2. The Food and Drug Administration's actions on pharmaceuticals, which is seeking to make use of RFID to tighten control over the nation's drug supply to ensure the availability, genuineness, and security of prescription drugs.
3. The Department of Agriculture's National Animal Identification System program, which is seeking to harmonize cross-species ID num-

bering and identification methods, largely with RFID, to safeguard the nation's food supply.

Because of their size and scope, these government-driven initiatives will force early implementation and testing of RFID technology, and as such, these mandates—or close to mandates—may well serve as the driver for wider-scale application of RFID in supply chain management.

The report then provides a discussion of what government's role should be in the advancement of RFID technology, focusing specifically on how the public sector can work to:

- Conduct trials and early implementations of RFID technology in a variety of areas to establish best practices.
- Assist in the establishment of common standards, which are essential for RFID to be interoperable.
- Foster and encourage research on the technology itself and its implications for business, government, and society.
- Develop and sponsor education on RFID for diverse audiences and purposes.
- Mitigate and adjudicate privacy concerns that may arise out of the use and development of RFID technology.

The research found numerous examples of where government is a lead user of RFID technology, not only in supply chain management, but in a wide variety of applications. RFID was found to be presently used to track everything from NASA's hazardous waste to library books in Frisco, Texas, to Los Angeles County's prisoners.

Will RFID be "the next big thing?" Throughout this research report, we are reminded that we are still in the early stages of this technological revolution, and as Assistant Deputy Undersecretary of Defense for Supply Chain Integration Alan Estevez (2005) recently wrote: "The real value of RFID lies not in what it can do today but in what it will do in the future" (n.p.). This report informs the reader on where we are today and where we are likely to go over the next decade as RFID more fully develops as a powerful influence in not only business and government, but in the way we live, work, and play.

Introduction

Introduction: The Next Big Thing?

In a famous scene in the movie *The Graduate,* Dustin Hoffman is given a one-word, can't-miss business tip: "plastics." Today, Taulli's (2004) one-word advice for business is an acronym: RFID—radio frequency identification. The promise of RFID could indeed make this technology the next "big thing," as the total RFID market (including tags, readers, software, and services) has been forecast to grow almost exponentially.

RFID could indeed create whole new ways of doing business, new conveniences, and vast, multi-billion-dollar opportunities—if the market projections are even halfway correct. According to IDTechEx (2005) and other leading market analysts, the development of the RFID market is projected to rapidly increase. As shown in Figure 1 on page 8, the RFID market, which stands at approximately $3 billion in 2005, will grow by roughly 800 percent by 2015. In fact, these market projections have been referred to as "hockey stick charts," as the take-off for RFID is forecast to be sharp and steep (Smith, 2005).

RFID has recently been characterized as a "disruptive technology," which Munarriz (2005) aptly characterizes as "a breakthrough that rattles the walls of the conventional … ultimately reshape[ing] our living experience" (n.p.). No less than Bill Gates, the founder, chairman, and chief software architect of Microsoft, recently labeled RFID as "a revolutionary technology" (Microsoft, 2004, n.p.). Likewise, the National Research Council's Committee on Radio Frequency Identification Technologies (2004) observed that we are presently at "a dynamic moment in the life cycle of this technology," one where "anything and everything seems possible" (p. 14).

What Is RFID?

RFID stands for radio frequency identification. For a glossary of RFID-related terms, see Appendix I.

As Rothfeder (2004) characterized the situation, "if ever there was a can't-miss, high-return technology, radio frequency identification would seem to fit the bill" (n.p.). But can RFID ever live up to its hype of being the next "best thing since sliced bread?" Tohamy (2004) cautioned that "RFID hype has taken on a life of its own" (p. 110). Indeed, Bob Parker, a vice president with the market research firm IDC, warned that RFID hype could "implode" (op. cited in Malykhina, 2005, n.p.). At present, we may well be in what Gartner describes as the "trough of disillusionment" phase in the evolution of a new technology, when hype gives way to reality (Roberti, 2005, "Is RFID Losing Momentum?" n.p.).

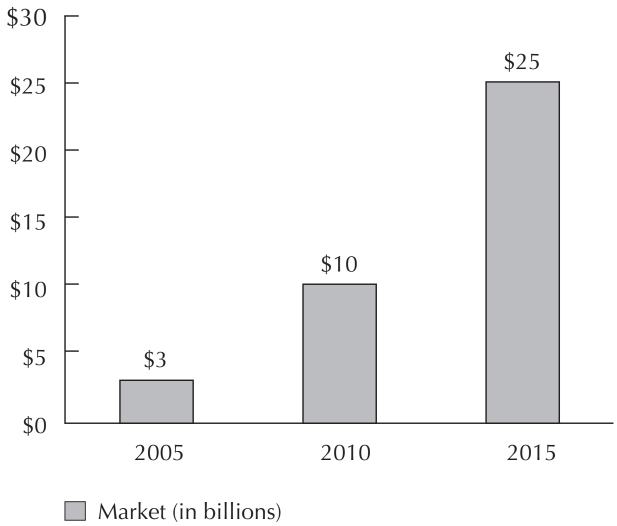
RFID's promise is rooted in the power of one word: *information.*

Information

Information is the fuel that drives the economy and the society today. The information fuel we use is about to get much richer and more potent. Picture the following circumstances:

- A worker at a distribution center can instantly identify each and every one of the items contained in every box on a pallet on the tongs of the forklift she is driving.
- A librarian can locate a book that had been hopelessly misshelved.

Figure 1: Projected Growth of the Overall RFID Market, 2005–2015



Source: *IDTechEx (2005).*

- A worker at a livestock processing facility can instantly access the identity and history of a cow.
- A hospital can locate critical medical devices instantly, wherever they are located throughout the facility.
- A pharmacist can tell that two bottles in his supply of a high in demand, highly addictive prescription drug are counterfeit.
- A military contractor in Baghdad can instantly locate the necessary spare to repair a Blackhawk helicopter for an imminent mission.
- A golfer can instantly locate his errant shot and retrieve the ball from the thicket where it landed.

All these scenarios are things that could not have been done yesterday but can be today, thanks to a new, old technology—radio frequency identification.

The Power of Identification

Throughout history, there has been a need to identify "things." By identifying things, we can sort, classify, request, ship, account for, and look for specific objects. We can do so for our personal use, for business purposes, and even for governmental functions.

As a society, we have come to expect that certain "things" would be—must be—uniquely identified. For instance, each and every automobile has a VIN—a vehicle identification number. Built on a coded system of letters and digits, the VIN conveys information on the specific vehicle in question. As such, it enables the vehicle to be traded, to be owned, to be maintained, and to be insured. Today, with a VIN, one can quickly pull up the complete history of a vehicle on the Internet. Without the power of the VIN to uniquely identify every automobile ever produced, much of the automotive industry and how we think about cars and car ownership would be far different (i.e., "That's really *my* Hummer!).

As with cars, people must be uniquely identified. This need for unique identification of people has existed throughout history. For instance, in the Middle Kingdom of Ancient Egypt, the Pharaoh Khasekem faced great difficulty in effectively distributing rations among the approximately 100,000 men "on duty" for constructing a pyramid project. Paralleling today's headlines, fraud was a common concern in this food distribution program. As such, Khasekem faced great accounting and inventory management difficulties, in that some workers would attempt to receive a daily food allowance several times. To combat this problem, Khasekem's administrators developed a system for identifying each of the workers (Ezzamel, 2004).

Our individual names may not be unique, and any James Johnson, Michael Smith, Miguel Torres, Emily Washington, or Youssef Islam (Cat Stevens) can relate stories—some humorous and some far more serious—where they have been mistakenly identified. Today, we are uniquely identified by a variety of entities, including:

- By the government, through Social Security numbers
- By employers, through employee ID numbers
- By universities, through student ID numbers
- By insurers, banks, credit card companies, and other financial institutions, through account numbers

While we have seen it historically necessary to uniquely identify such highly important assets as ourselves and our vehicles, the vast majority of "things" have remained identified by their class, category, or type. Until two decades ago, the human eye served as the primary mechanism for discriminating between objects of different types, whether they be different species of trees, different brands of ketchup, or different forms of munitions. However, with the advent of bar code technology, for the first time, machines—in addition to people—could identify objects.

The Big Picture: Automatic Identification and RFID

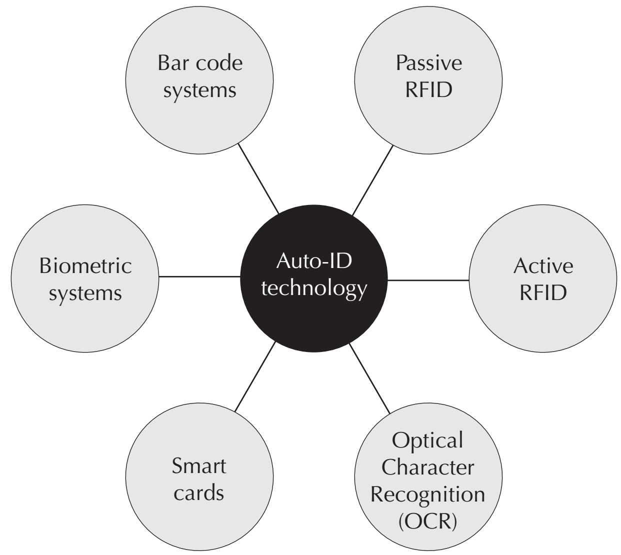
Automatic Identification, or auto-ID, represents a broad category of technologies that are used to help machines identify objects, humans, or animals. As such, it is often referred to as automatic data capture, as auto-ID is a means of identifying items and gathering data on them without human intervention or data entry. As can be seen in Figure 2, the omnipresent bar code is itself a form of auto-ID technology.

RFID is also a type of auto-ID technology. Sometimes referred to as dedicated short-range communication (DSRC), RFID is "a wireless link to identify people or objects" (d'Hont, 2003, p. 1). RFID is, in reality, a subset of the larger radio frequency (RF) market, with the wider market encompassing an array of RF technologies, including:

- Cellular phones
- Digital radio
- Global Positioning System (GPS)
- High-definition television (HDTV)
- Wireless networks (Malone, "Sensing the Future," 2004)

RFID is a technology that already surrounds us. First, if you have an automobile that was manufactured after 1994, the car uses RFID to verify that it is your key in the ignition. Otherwise, the car won't start. If you have an Exxon/Mobil Speedpass™ in your pocket, you're using RFID. If you have a toll tag on your car, you're using RFID. If you have checked out a library book, you've likely encountered RFID. If you've been shopping in a department store or an electronics retailer, you've most certainly encountered RFID in the form of an EAS (Electronic Article Surveillance) tag.

Figure 2: The Family of Automatic Identification Technologies



A Brief History of RFID

RFID is by no means a "new" technology. It is fundamentally based on the study of electromagnetic waves and radio, which was rooted in the 19th century work of pioneers such as Michael Faraday, James Clerk Maxwell, and Guglielmo Marconi. The idea of using radio frequencies to reflect waves from objects dates back as far as 1886 to experiments conducted by Frederick Hertz. Radar as we know it was invented in 1922, and its practical applications date back to World War II, when the British used the IFF (Identify Friend or Foe) system to identify enemy aircraft on its coasts (Landt, 2001). There is even a school of thought that attributes the first use of RFID to spy work done in the former Soviet Union (see "Is RFID a Russian Plot?" on page 10).

Many, however, point to a seminal academic paper on the subject as the foundation for RFID. In 1948, Harry Stockman published "Communication by Means of Reflected Power," in which he laid out the basic concepts for what would become RFID. However, Stockman (1948) himself predicted that

Is RFID a Russian Plot?

Born in Saint Petersburg in 1896, Léon Theremin was a Russian inventor, best known for his inventions in the area of electronic musical instruments. In 1919, he created his best-known invention, the Theremin. However, in the midst of the Russian Civil War, he was forced to emigrate to the United States. Theremin had a laboratory in New York in the early 1930s, and he conducted the first-ever electronic orchestra, performing at Carnegie Hall in 1932. While Theremin had flourished during his time in America, he returned to the Soviet Union in 1938 under mysterious circumstances. Years later it was confirmed that Theremin had been kidnapped by Soviet KGB agents and forced to return to his native land.

Why kidnap an inventor of musical instruments? After being imprisoned and then forced to work in the gold mines, Theremin's scientific and audio knowledge was then put to use by the KGB. In short, Theremin invented the first "bug" (or covert listening device) that did not need its own power source, which made it far less detectable to sweeps for listening devices. Theremin's bug—named "The Thing"—was the first listening device to use inducted energy from radio waves of one frequency to transmit an audio signal on another. A Theremin-created bug was embedded in a wooden plaque and presented to the U.S. ambassador to the Soviet Union by Russian schoolchildren, and it hung undetected for years in the U.S. Embassy in Moscow.

Theremin did return to the U.S. in 1991, before his death in Moscow in 1993 at the age of 97. Léon Theremin's remarkable life and career were captured in the documentary film *Theremin—An Electronic Odyssey*, which won awards at the Sundance Film Festival in 1994 (Glinsky, 2000).

"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" (p. 1202).

There were fits and starts in the application of RFID technology, with what may be the fundamental patent (now expired) being filed in 1973 by Charles Walton, a former IBM researcher who left to form his own company, Proximity Devices, in Sunnyvale, California. Walton's patent was for a radio-operated door lock, where a dormant tag was sent a minute electrical current by a radio transceiver to recognize the key it was attached to. While the board of directors at General Motors rejected Walton's invention as being "too Buck Rogers," his idea was bought by the lock-making firm Schlage to make electronic locks that could be opened by a user waving a keycard in front of a reader—the fundamental idea behind the access cards that are so pedestrian today (Takahashi, 2004).

In fact, it would take decades of development in a variety of different fields—computers, radar and radio technology, supply chain management, transportation, quality management, and engineering—before RFID technology became a reality, seeing limited use in asset management, livestock tracking, transportation, and even payments. The U.S. government helped advance the technology during this time, as the Los Alamos National Laboratory in New Mexico became a leading center for research and development into radio frequency technology (Shepard, 2005). For instance, for well over a decade now, all railroad freight cars in North America have been tracked by the Rail and Intermodal Asset Tracking System. Each carries an active RFID transponder, and as the cars pass key points at rail switching yards, the rail car's identity is read and its location reported to a common tracking system (Anonymous, "RFID Unites the Supply Chain," 2005). Likewise, since 1997, when Exxon/Mobil first introduced the novel Speedpass transponder device to allow drivers to make credit gasoline purchases by waving a key fob with a tiny transponder in front of the gas pump, the program has gown to an estimated 6 million drivers today (Fuquay, 2004).

Much of the current developments in the RFID area can be traced to the work of Dr. Sanjay Sarma. In the mid-1990s, Sarma, then an engineering professor at the Massachusetts Institute of Technology (MIT), along with a departmental colleague, David Brock, were working on a robotics problem, namely how to have a machine recognize and respond to items in its environment. Robotic engineers have struggled for decades in attempts to devise ways for robots to see with mechanical eyes in a way that emulates human sight. Sarma and Brock asked a "what if" question: What if, instead of having a robot attempt to "recognize" objects through viewing them, what if objects, with the use of an electronic marker, could identify themselves to a robot? With the use of a simplified marker, or tag, the robot could be informed of the presence of an item and then use its identifier to access a database to obtain specific information on the item and what it should do with it (Manjoo, 2003). In 1999, Sarma, Brock, and Kevin Ashton co-founded the Auto-ID Center at MIT, looking to examine ways that RFID technology could be used in commercial applications.

Over the last six years, RFID technology has suddenly become "hot," with considerable thought and investment being made to build on Stockman's and Sarma's visions.

RFID and Bar Codes

Senator Patrick Leahy described RFID as a bar code "on steroids" (quoted in Fox and Rychak, 2004, n.p.).

The bar code has become a part of every product we buy, having become "the ubiquitous standard for identifying and tracking products" (Douglas, 2005, n.p.). Bar code technology has been institutionalized across most industries and around the globe, accounting for billions of bar code scans daily. Still, while the bar code and the Universal Product Code (UPC) have become omnipresent and enabled a host of applications and efficiencies (see Brown, 1997), they only identify a "thing" as belonging to a particular class, category, or type.

Due to its structure (as shown in Figure 3), a bar code cannot *uniquely* identify the specific object

Figure 3: Anatomy of a Bar Code

The 'Juicy Fruit' Origins of the Bar Code

One small step that became one giant leap for global commerce began at Marsh's Supermarket in Troy, Ohio. Just after the store opened on June 26, 1974, a customer went in to buy a pack of Wrigley's Juicy Fruit gum. Yet, his checkout was unlike any other that had preceded it, as this was the first product purchased through the scan of a bar code. Today, that humble pack of gum is now housed at the Smithsonian Institute's National Museum of American History, joining the ranks of American innovations that have similarly transformed the way we live, work, play, and shop (Brown, 1997).

The introduction of the bar code was the culmination of over 30 years of research. The first patent for automatic product coding was developed by two Drexel University graduate students, Bernard Silver and Norman Woodland. Their system, based on ink patterns that glowed when exposed to ultraviolet light, proved to be unstable in practice to be commercialized. However, IBM and NCR eventually developed the foundations of the bar coding system used globally today (Bonsor, 2003).

While the bar code was intended to improve efficiencies in the grocery industry, it has become ubiquitous in the identification of everything—from gum to computers to blood products. In fact, the Uniform Code Council (UCC) estimates that there are presently 5 billion bar code scans each day around the world (Mroz Consulting, 2005).

before you. For instance, while the bar code on a box of cereal can tell you the type, size, and producer of that box of cornflakes, it cannot tell you:

- Where the cereal was boxed
- When the cereal was produced
- The lot and/or production run during which the cereal was made
- Where the cereal box traveled in its journey to the shelf

In sum, a bar code on an item can identify *only* the product and its manufacturer. Thus, a bar code on any one package of sliced meat in a grocery store is the same as on any other of a particular type/size from a particular firm. Likewise, the bar code on a case or pallet of military supplies cannot tell one shipment from another. As such, it is impossible to tell from the bar code such important questions as:

- Where was that particular item manufactured?
- In which lot/shift was the item manufactured?
- When was the product manufactured?
- When will the product expire?

Conceptually, bar codes and RFID are indeed quite similar, as both are auto-ID technologies that are intended to provide rapid and reliable item identification and tracking capabilities. The primary difference between the two technologies is the way in which they "read" objects. With bar coding, the reading device scans a printed label with optical-laser or imaging technology. However, with RFID, the reading device scans, or interrogates, a tag using radio frequency signals. Thus, referring to RFID as "radio bar codes," as many do, is a disservice to the technology, one that confuses the basics of the technology.

Table 1: Comparison of RFID and Bar Codes

Bar Code Tags	RFID Tags
Bar codes require line of sight to be read.	RFID tags can be read or updated without line of sight.
Bar codes can only be read individually.	Multiple RFID tags can be read simultaneously.
Bar codes cannot be read if they become dirty or damaged.	RFID tags are able to cope with harsh and dirty environments.
Bar codes must be visible to be logged.	RFID tags are ultra thin and can be printed on a label, and they can be read even when concealed within an item.
Bar codes can only identify the type of item.	RFID tags can identify a specific item.
Bar code information cannot be updated.	Electronic information can be overwritten repeatedly on RFID tags.
Bar codes must be manually tracked for item identification, making human error an issue.	RFID tags can be automatically tracked, eliminating human error.

The specific differences between bar code technology and RFID are summarized in Table 1. In summary, however, there are five primary advantages of RFID over bar codes. These are:

1. Each RFID tag can have a unique code that ultimately allows every tagged item to be individually accounted for.
2. RFID allows for information to be read by radio waves from a tag, without requiring line-of-sight scanning or human intervention.
3. RFID allows for virtually simultaneous and instantaneous reading of multiple tags in the vicinity of the reader.
4. RFID tags can hold far greater amounts of information, which can be updated.
5. RFID tags are far more durable.

Bar codes yield information indicating the category of an item. In contrast, an RFID tag can present much more robust *serialized*—"granular"—information on a specific item, identifying it as a unique thing. RFID tags are thus a "supercharged" item identifier, as compared to the bar code (van Grinsven, 2004).

Yet, RFID tags, with limited memory themselves, are intentionally designed not to be the repository of this unique item information. Rather, through a coding system known as the Electronic Product Code (EPC), the function of the RFID tag is clear. As explained by Ping Li, assistant director for IT services at the Transportation Security Administration, "The tag is a record pointer to a richer set of information—the flag above the ground for a complete information system" (quoted in Aitoro, 2005, n.p.). In effect, the tag is thus a "license plate" for each tagged item, directing the user via the Internet to the database where complete descriptive information about the item is housed.

Item-level information can be key for locating a specific item or lot of items—for example, to locate expired food perishables or tires from a particular production run for a product safety recall. Since they are not "programmable," bar codes also do not contain pricing or store-specific information.

It is also important to bear in mind the fundamental temporal differences between bar codes and RFID.

Table 2: RFID Applications

Traditional RFID Applications	Emerging RFID Applications
Security/access control	Warehouse management
Electronic article surveillance	Supply chain management
Asset/fleet management	Reverse logistics
Mass transit	Shipment tracking
Library access	Asset tracking
Toll collection	Retail management
Animal identification	Document tracking
	Anti-counterfeit
	Advance access control
	Mass transit—monthly and single trip
	Airline baggage handling
	Aircraft parts and tools
	Healthcare applications
	Regulatory compliance
	Payments

With bar code technology, information on the item is obtained only when someone takes the action of scanning the bar code label with a reader—and only that particular reader. In contrast, an item tagged with RFID is always "turned on" and available to be read—and perhaps by multiple readers at the same time. Thus, while a bar-code-labeled item can only be read discretely, an RFID-tagged item can be read or monitored continuously. In practical terms, a bar code can only tell you where an item of a particular class *was* when it was last scanned, while RFID can tell you precisely where a particular item *is* at any given moment.

This granular information can enable a whole host of applications that are unimaginable with bar code technology (see Table 2). In the end, it is likely that RFID will supplement rather than supplant bar code technology for tracking items in supply chain management and other applications in organizations. They are by no means mutually exclusive technologies. They will most likely co-exist on product and shipping labels for at least the next decade. Indeed, some of the most creative and cost-beneficial applications may come from combining and nesting RFID and bar codes together, where RFID tags/labels may be used to identify large groups of items and bar codes remain as the tracking device for individual items.

Supply chain management applications play a central role in RFID's development today—led by initiatives both by the Department of Defense and by private sector firms, led by American retail giants such as Wal-Mart, Target, and Albertson's. These supply chain mandates are spurring a flurry of activity regarding RFID and grabbing headlines today. However, there are also inventive uses for RFID in a whole host of applications beyond the realm of distribution centers and supply chain management. From healthcare to animal identification to file and evidence tracking and even in the world of sports (see "Golf Balls: RFID's 'Killer App'" on page 14), RFID technology holds great promise to—in the vernacular of management guru Tom Peters (2003)—"reimagine" processes and paradigms across the business and government sectors. In fact, organizations are finding that these non-supply-chain RFID projects are more "doable" today, with more solid business cases and return on investment (ROI) prospects than distribution and logistics applications. In many cases, whole new companies today—and perhaps industries tomorrow—are being built on entrepreneurs and techies alike asking "what if" questions about solving real problems through the application of RFID technology (see "The Smart Toilet" on page 15).

Thus, as with many aspects of life, the unintended consequences of RFID may indeed be the most important ones. Gary Cooper, chief technology officer for Tyson Foods, stated that while his firm has experienced both successes and failures in working with RFID technology and EPC, there are also the unexpected "aha! moments" that cannot be predicted or anticipated (op. cited in Albright, "Testing Key to RFID Success," 2005, n.p.). Indeed, these new and imaginative uses of RFID and the information and visibility the technology can bring may in time create whole new ways of doing things, create new levels of security, and create new business opportunities in the process. Reik Read, the lead RFID analyst with the investment firm Robert W. Baird & Company, commented that these non-supply-chain uses "are starting to pan out

Golf Balls: RFID's "Killer App"

Anyone who has picked up a golf club has been there. You hit your drive off the first tee, and it goes, and goes, and goes—where? All golfers have spent countless hours combing the banks of creeks, looking in crevices, and wading through thickets in often fruitless searches for their wayward shots. But what if there was a high-tech way for the ball to tell you where it was and guide you to it? Radar Golf, a small company based in Roseville, California, is seeking to RFID-enable the game of golf with its Radar Golf System. Such a prospect led Stephanie Stahl (2005), the editor of *InformationWeek*, to say that finding lost golf balls may be the "killer app" for RFID in the consumer world.

Radar Golf has developed a golf ball, manufactured by a Chinese contractor, that has an RFID tag embedded inside its core. The ball has been certified as conforming to the rigorous standards of the United States Golf Association (USGA), enabling it to be used in tournament play. The company's patented Ball Positioning System (BPS) is built into a handheld unit, which is essentially an RFID reader that transmits a specific radio frequency signal to search for the lost ball. It provides a visual LCD signal strength display and pulsed audio tone feedback to the golfer looking for his/her ball, with the beep increasing (like a Geiger counter) as the golfer nears the location of the wayward ball. The BPS presently has a detection range of up to 100 feet (LaPedus, 2005).

The company began marketing the system in mid-2005. The Radar Golf System retails for $249, which includes a dozen golf balls (additional sets of a dozen balls retail for $39). It plans to license the technology to other golf ball manufacturers to equip their branded balls with RFID tags (LaPedus, 2005).

in the form of applications you would have never expected." Read's comments were echoed by Mike Willis, Intermec Technologies' vice president and general manager for RFID, who recently observed, "Today the simple applications are the ones making the most impact" (opinions cited in L. Sullivan, "Where's RFID Going Next?," 2005, n.p.).

Report Overview

This report comes at an exciting time in the life cycle of RFID. Indeed, while we have seen that RFID is not a new technology, we may be at an inflection point in the course of the technology and, indeed, in its impact on business, society, and government. The public sector has a multifaceted role to play in the RFID revolution, as government will be:

- Users of the technology
- Heads of supply chains using the technology
- Funding and conducting research into the technology
- Helping to set standards and best practices in the technology
- Regulating—and perhaps restricting—the technology

Thus, it is vital that public executives have an understanding of the capabilities and limitations of RFID technology, along with an appreciation of the potential issues it will raise for them and an array of stakeholders as actors in a complex, rapidly evolving technological landscape.

In the next section of this report, we look at how RFID operates. Then we turn our attention to the drivers behind RFID today and its application to supply chain management, looking to answer the questions of "why RFID?" and "why now?" We look at the consequences of the mandates of the Department of Defense and leading retailers, including how suppliers are looking to comply and how organizations are looking to deal with the data management issues that arise out of the increased visibility RFID will bring. We then examine three specific cases where RFID is being employed in supply chain management today, coming as the result of both federal mandates and innovation in the private sector. These cases are:

- The Department of Defense's supply chain mandate
- The Food and Drug Administration's actions on pharmaceuticals
- The Department of Agriculture's National Animal Identification System program

We then turn our attention to the proper role of government at all levels in the midst of the progression of RFID. We consider the role that the public sector can and is playing in terms of carrying

The Smart Toilet

Long Beach, California–based AquaOne Technologies has begun marketing perhaps the most unexpected RFID application—one that's literally "in the toilet." AquaOne's H2Orb system is a faster, better, and cheaper way of automatically monitoring toilets to prevent them from leaking and/or overflowing, which can cause thousands of dollars in damage to private homes and cost 10 to 100 times more damage in commercial properties, hotels, and public venues.

It was inspired by a conversation the company's president and founder, Richard Quintana, had with a Texas Instruments (TI) engineer about the use of RFID in car ignition systems. In fact, the H2Orb system uses the same TI 134.2 KHz chips used in the auto security devices. The control unit for the H2Orb system sounds an alarm and shuts down the water source automatically whenever an "adverse event" is sensed. A passive RFID sensor positioned in the bowl sends a signal when an overflow is about to occur. Likewise, a second passive RFID sensor, positioned in the tank, can detect slow leaks or an open flapper.

AquaOne markets systems for both commercial and home applications, with basic models starting at under $100. There is a huge potential market for such devices, as there are approximately 800 million toilets in the United States alone. Beyond the international market for business and private use, there is also international interest in using the device to aid countries with severe drought conditions to better conserve water for their populations (Swedberg, "RFID Device Serves as Plumber's Helper," 2005).

out RFID pilots and implementations—both in the supply chain and in a whole host of other applications—gaining experiences that can be shared and setting best practices in the process. We also analyze the role that government can play in fostering the development of global industry standards that will enable greater interoperability and power in the "Internet of things" that is being created. We also explore the government's potential to assist in research efforts—in a variety of venues and streams—that will be necessitated by the rise of RFID technology, everything from the "nuts and bolts" of how to make the technology work best to the "big picture" ethical and societal issues. We also look at the privacy issues that arise attendant to RFID technology, partly but not totally due to fears and misapprehensions about a technology that can extend visibility beyond the supply chain, the hospital, and the workplace. We conclude with a look toward the future and the exciting possibilities that are being brought about by what one futurist has labeled the "weird new media revolution" that RFID is enabling. RFID promises to be one of the most important technologies of our time, and this report examines both the practicalities of and the prospects for the technology.

RFID 101: The Basics of the Technology

Introduction

What is RFID? Surveys have consistently shown a lack of RFID awareness and an overall lack of understanding about the actual capabilities—and limitations—of automatic identification technologies.

- According to the most recent large-scale national survey on RFID, less than half of the general public (41 percent) have an awareness of RFID technology (Collins, "Consumers More RFID-Aware, Still Wary," 2005).
- A recent survey likewise showed that board-level executives were roughly equally divided between those who were up to speed on RFID technology (45 percent) and those who had no idea what it was (43 percent) (Best, 2004).
- There is an "RFID gender gap." As first identified by Wyld ("What's the Buzz on RFID?" 2004), men are more than twice as likely as women to be aware of RFID and significantly more likely than women to perceive the whole concept of using RFID to track products as being a "good idea." Thus, as has been the case with other radical technologies (cell phones, the Internet, high-definition television), men tend to be in the lead in terms of their overall knowledge of and interest in the technology.

The 'Short-Answer Essay'

Kenneth Porad, who is in charge of Boeing's auto-ID program, explained RFID as being "like shining a flashlight at a mirror and reflecting the light back" (quoted in Sternstein, "FAA Gives Go-ahead to RFID," 2005). While this analogy is an easy way to explain the technology to a lay audience, an engineer might readily object, as it is not *technically* correct. This is because with RFID, the communication occurs through the transference of data not through audio or light, but over electromagnetic waves in radio frequency communication.

Three elements are necessary for an RFID system to work:

- Tags
- Readers
- Software/information processing

In a nutshell, the technology works like this: The tag is the unique identifier for the item it is attached to. The reader sends out a radio signal, and the tag responds with a signal to identify itself. The reader then converts the radio waves returned from the tag into data that can be passed on to an information processing system to filter, categorize, analyze, and enable action based on the identifying information.

What's in a Tag?

There are three essential components that combine to form an RFID tag:

- Chip
- Antenna
- Packaging

An RFID tag has at its heart an integrated circuit (IC), which contains the unique identifying data about the object to which is it is attached. One of the identifiers—but not the only one—that can be used to identify the item uniquely with an RFID tag is the Electronic Product Code, or EPC. The IC is attached to a small antenna, which most commonly is a small coil of wires. The third element is the packaging of the tag that contains and protects the IC and the antenna. This packaging can come in a variety of sizes and forms, geared to meet the requirements of the specific application. In fact, RFID tags can take a variety of forms, including:

- Smart labels
- Keys or key fobs
- Watches
- Smart cards
- Disks and coins, which can be attached to an item with a fastening screw
- Mount-on-metal, with special construction that creates a buffer between the tag and the item to reduce interference and heighten readability
- Glass transponders, which can be implanted under the skin of a human or animal

Hitachi has developed the mu-chip, a very tiny (.4 millimeter square) RFID tag that is the size of a grain of rice (Anonymous, "Micro Tracker," 2004). As explained in "Is RFID Tough Enough?" RFID tags can function in harsh environmental conditions and temperature extremes.

Is RFID Tough Enough?

One of the principal advantages that RFID tags have for identifying products, items, and equipment is the fact that the tags are far more durable than bar codes. If a bar code label is covered with grime or mud, it is unreadable. If a bar code is torn or disfigured, it can no longer function as an identifier. However, RFID tags are highly durable, and as long as they are not destroyed (either physically or with an electromagnetic pulse of sufficient strength to do so), passive tags will be ready to transmit indefinitely.

RFID tags and labels can work effectively, even in harsh environments with excessive dirt, dust, moisture, and in temperature extremes. They can function in both extreme heat and cold, with a functional temperature range between –25 and 70 degrees Celsius. Some tags specifically designed for industrial applications can function well beyond the boiling point—up to 250 degrees Celsius. Most tags can withstand the high-power pasteurization process and X-rays. The only caveat to the latter would be that most silicon-based electronic circuits are erased by the gamma radiation commonly used for sterilization (Zebra Technologies, 2004).

Passive Tags

There are three basic categories of tags—passive, active, and semi-passive. A summary of the differences between passive and active is presented in Table 3 on page 18.

Passive tags are already very familiar to us, as we see simple examples in the form of the Electronic Article Surveillance, or EAS, tags used throughout the retail industry. With a passive tag, the tag basically has no power source, and as such, it is only "on" and able to transmit information when it is within range of an RFID reader. Passive tags function through a process known as "energy harvesting," wherein energy from the reader is gathered by the tag, stored momentarily, and then transmitted back to the reader at a different frequency.

In brief, the science of a passive RFID system works like this. The reader sends out electromagnetic waves, and a magnetic field is formed when the signal from the reader "couples" with the tag's antenna. The passive RFID tag draws its power from this magnetic field, and it is this power that enables the tag to send back an identifying response to the query of the RFID reader. When the power to the silicon chip on the tag meets the minimum voltage threshold required to "turn it on," the tag then can respond to the reader through the same RF wave. The reader then converts the tag's response into digital data, which the reader sends on to the information processing system to be used in management applications (see "'High-Tech Marco Polo'" on page 18).

This all happens almost instantaneously. In fact, today's RFID readers are capable of reading tags at a rate of up to 1,000 tags per second. Through a process known as "simultaneous identification," most RFID systems can capture data from many tags within range of the reader's antenna almost simultaneously. In reality, however, the tags are responding individually—within milliseconds of one another—in a manner to prevent tag and reader collision in their signals through response protocols.

"Smart labels" are a particularly important form of passive RFID tag. A smart label is an adhesive label that is human and quite often machine readable with

Table 3: Differentiating Passive and Active RFID Tags

Passive Tags	Active Tags
Operate without a battery	Powered by an internal battery
Less expensive	More expensive
Unlimited life (because of no battery)	Finite lifetime (because of battery)
Less weight (because of no battery)	Greater weight (because of battery)
Lesser range (up to 3 to 5 meters, usually less)	Greater range (up to 100 meters)
Subject to noise	Better noise immunity
Derive power from the electromagnetic field generated by the reader	Internal power to transmit signal to the reader
Require more powerful readers	Can be effective with less powerful readers
Lower data transmission rates	Higher data transmission rates
Fewer tags can be read simultaneously	More tags can be read simultaneously
Greater orientation sensitivity	Less orientation sensitivity

a bar code. However, the label is also embedded with an ultra-thin RFID tag "inlay" (the IC and a printed antenna). Smart labels combine the functionality of passive RFID tags with the convenience and flexibility of either being pre-printed and pre-coded for use or printed "on demand." Looking ahead, analysts have predicted that the vast majority of RFID tags will come in the form of smart labels. In fact, it has been estimated that smart labels will constitute 99.5 percent of the trillion tags forecast to be in use a decade from now (Anonymous, "Expert Predicts Lucrative Future for RFID Smart Labels," 2005).

Active Tags

An *active tag* functions in the same manner as its passive counterpart, but it contains a fourth element—an internal battery that continuously powers the tag. As such, the tag is always "on" and transmitting the information contained on its silicon chip. The active tag is only readable, however, when it is in the reading field of an RFID reader. However,

'High-Tech Marco Polo'

In *Wired* (2004, n.p.), Ryan Singel offers one of the best analogies of the workings of RFID, likening it to a "high-tech version of the children's game Marco Polo." In a passive RFID system, the reader sends out a signal on a designated frequency, querying if any tags are present in its read field (the equivalent of yelling out "Marco" in a swimming pool). If a chip is present, the tag takes the radio energy sent out by the reader to power it up and respond with the electronic equivalent of kids yelling "Polo" when they are found.

the battery significantly boosts the effective operating range of the tag. Thus, while a passive tag can only be read at a range of a few yards, active tags can be read at a distance of 10 to 30 yards or more. However, while the useful life of an active tag is limited by the life of the onboard battery (typically five years at present), a passive tag has an unlimited life span. Due to the need for a battery, active tags will always cost more and weigh more than passive tags.

Semi-Passive Tags

A third tag category is what is referred to as a *semi-passive tag*. With semi-passive tags, the RFID tag is combined with a sensor, enabling the semi-passive tag to sense the environment. This sensing capacity can be for such environmental monitoring as:

- Temperature
- Shock or vibration
- Movement

Like an active tag, this category of tag has a battery, which both powers the sensing capability and extends the readability range of the tag. Semi-passive tags have found uses where it is critical to monitor both the location and condition of an item. As tag prices fall, it is very likely that there will be more and unique uses for such tags.

Tag Memory

RFID tags can also be classified by their memory capabilities, which can come in three forms:

1. **Read-only tags:** Store data that cannot be changed.

2. **Read/write tags:** Store data that can be altered or even re-written over the original data.
3. **Combination tags:** Have some data that is permanently stored on the tag, along with additional memory capacity that is available for updates and/or sensing data.

While most tags function in the "license plate" mode, with limited memory capacity (generally 96 or 128 bits at present), far more sophisticated tags are available to meet the needs of specific applications.

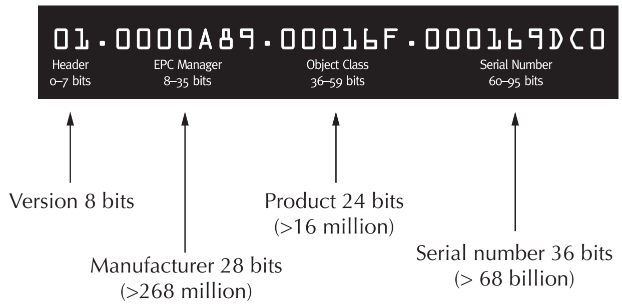
The Electronic Product Code

The EPC is designed to be the unique, item-level identifier for the item to which it is attached. As described earlier, the EPC information on the RFID tag is the pointer to where the complete information on the item is stored. While the origins and importance of the EPC will be discussed at length later in this report, in this primer on RFID technology, we will simply describe what it is and what it tells us. As can be seen in Figure 4, there are four elements that make up the 96-bit capacity Electronic Product Code. These are:

1. **The Header (or Version):** Identifies the length of the EPC number, including the code type and version in use (up to 8 bits).
2. **The EPC Manager (or Manufacturer):** Identifies the company or entity responsible for managing the next two EPC elements (up to 28 bits).
3. **The Object Class (or Product):** Identifies the class of item (for example, the Stock Keeping Unit [SKU] or consumer unit) (up to 24 bits).
4. **The Serial Number:** Identifies a unique serial number for all items in a given object class (up to 36 bits).

There are literally hundreds of trillions of unique identifications possible in the 96-bit EPC structure; thus, manufacturers should not have to worry about running out of EPC numbers for unique identifiers for each of their product types for many decades or more. The EPC data structure can generate approximately 33 *trillion* different unique combinations, which, according to Helen Duce of Cambridge University, would be enough to label all of the atoms in the universe (cited in Anonymous, "Pushing the Envelope," 2003). In fact, according to projections

Figure 4: Electronic Product Code (EPC)



from the National Research Council's Committee on Radio Frequency Identification Technologies (2004), this will allow for each of the billions of people on earth to have billions of tags each.

This can be contrasted with the 12-bit structure of the current UPC data structure. As can be seen in Figure 3 on page 11, there is a "memory" limitation on bar codes, because with their coding structure they can identify "only" 100,000 products for each of 100,000 manufacturers. As Parkinson (2003) points out, this may simply not be enough for companies operating in the global, modern economy.

The EPC framework outlines six classes of tags, with an ascending range of capabilities (see Table 4).

Table 4: Electronic Product Code (EPC) Tag Classes

EPC Tag Class	Tag Class Capabilities
Class 0	EPC number is factory programmed onto the tag and is read-only
Class 1	Read/write-once tags are manufactured without the EPC number (user programmable)
Class 2	Class 1, plus larger memory, encryption, and read/write capabilities
Class 3	Class 2 capabilities, plus a power source to provide increased range and/or advanced functionality (such as sensing capability)
Class 4	Class 3 capabilities, plus an active transmitter and sensing
Class 5	Class 4 capabilities, plus the ability to communicate with passive tags (essentially a reader)

Source: *EPCGlobal.*

What Does an RFID Reader Do?

An RFID reader consists of three essential elements:

- An antenna
- A transceiver
- A decoder

RFID *readers,* which are also referred to as *interrogators,* can differ quite considerably in their complexity, depending upon the type of tags being supported and the functions to be fulfilled. Readers can be large and fixed, or small, handheld devices. However, the read range for a portable reader will be less than the range that can be achieved using a fixed reader, as the effective read range is determined by the size of the antenna, the efficiency of that antenna, and the power of the transmitter. Readers can have a single antenna, but multiple antennas allow for:

- Greater operating range
- Greater volume/area coverage
- Random tag orientation

The RFID reader—either continuously (in the case of a fixed-position reader) or on demand (as with a handheld reader)—sends out an electromagnetic wave to inquire if there are any RFID tags present in its active read field. When the reader receives any signal from a tag, it passes that information on to the decoding software and processes it for forwarding to the information system it is a part of.

Recently, it has been forecast that as soon as 2007, RFID readers will not be just distinct, dedicated devices. Rather, RFID reading capabilities will soon be capable of being integrated into cell phones, personal digital assistants (PDAs), and other electronic devices—technology that is being tested even today (Thomas, 2005).

'What's the Frequency, Kenneth?'

Frequency designates the intensity of the radio waves used to transmit information. Frequency is of primary importance when determining data transfer rates (bandwidth), in that the higher the frequency, the higher the data transfer rate. In principle, any radio frequency (RF) system works much akin to your car radio (assuming you don't have satellite radio!). For instance, all FM radio stations in the United States must operate between 88 and 108 MHz. Thus, if you are currently tuned to 97.1 FM, it means that your radio is tuned at the moment to receive waves repeating 97.1 million times per second.

RFID Frequencies

Four common frequencies are used in RFID systems. These are outlined in Table 5.

Each of the four frequencies has its own properties, and there are a variety of reasons why each is used in specific applications. An overview of the characteristics of each frequency range is provided in Table 6.

While work is progressing to harmonize world standards in each of the four frequency ranges, frequency restrictions imposed by governments around the world have been a significant obstacle facing RFID development (Moore, 2003). For instance, while Europe uses 868 MHz for UHF systems and the U.S. uses 915 MHz, Japan and China currently do not allow any use of the UHF spectrum for RFID. National governments also regulate the power of the readers to limit interference with other devices (Fox and Rychak, 2004).

Read Range of RFID Systems

The read range refers to the working distance between a tag and a reader. The range that can

Table 5: Common RFID Frequencies and Read Ranges

Frequency Band	Description	Range
125–134 KHz	Low frequency	To 18 inches
13.553–13.567 MHz	High frequency	3–10 feet
400–1,000 MHz*	Ultra-high frequency (UHF)	10–30 feet
2.45 GHz	Microwave	10+ feet

*Most RFID systems in the UHF band operate between 860 and 930 MHz.

Source: *Adapted from Intermec (2003).*

Table 6: Characteristics and Applications of RFID Frequency Ranges

Frequency Band	System Characteristics	Example Applications
Low (LF) 100–500 KHz (typically 125–134 KHz worldwide)	• Short read range (to 18 inches) • Low reading speed • Relatively inexpensive • Can read through liquids • Works well near metal	• Access control • Animal identification • Beer keg tracking • Inventory control • Automobile key/anti-theft systems
High (HF) (typically 13.56 MHz)	• 13.56 MHz frequency accepted worldwide • Short to medium read range (3–10 feet) • Medium reading speed • Can read through liquids/works well in moist environment • Does not work well near metal • Moderate expense	• Access control • Smart cards • Electronic article surveillance • Library book tracking • Pallet/container tracking • Airline baggage tracking • Apparel/laundry item tracking
Ultra High (UHF) 400–1,000 MHz (typically 850–950 MHz)	• Long read range (10–30 feet) • High reading speed • Reduced likelihood of signal collision • Difficulty reading through liquids • Does not work well in moist environments • Experiences interference from metals • Relatively expensive	• Item management • Supply chain management
Microwave 2.4–6.0 GHz (typically 2.45 or 5.8 GHz)	• Medium read range (10+ feet) • Similar characteristics to UHF tags, but with faster read rates	• Railroad car monitoring • Toll collection systems

be achieved in an RFID system is determined by five variables:

- The frequency being used
- The power available at the reader
- The power available within the tag
- The size of the reader and tag antennas
- Environmental conditions and structures

As seen in Table 6, higher frequency tags have far greater read ranges than tags operating at lower frequencies. This is because, all things being equal, power is the key element in this process. In the previously described energy-harvesting technique that is employed to power passive tags, it is important to note that the process returns the signal with only a fourth of the power transmitted to power it up. Thus, with the relative—and unavoidable—inefficiency of the process, in order to double the read range, the power used must be increased 16 times (Committee on Radio Frequency Identification Technologies, National Research Council, 2004).

Making It Automatic—Read Rates

Finally, as is the case with so many technologies, while the physics are relatively simple, the devil is in the details to get readers and tags to properly communicate. While the goal for the technology to be "automatic" and hands-off necessitates 100 percent read rates, such has not always been the case in pilots and early implementations (Sliwa, "Retailers Drag Feet on RFID Initiatives," 2005). Several variables can dramatically affect read rates in practice. These include:

- Tag selection and placement
- Antenna selection and placement
- Reader (interrogator) settings (Sirico, 2005)

According to Robb Clarke (2005), founding director of Michigan State University's RFID Lab, it must be remembered that experiments and pilots of tags and readers in controlled circumstances "represent the best possible scenarios for readability." And, as the shift is made to actual warehouse conditions and higher quantities/higher speeds, readability can be significantly challenged (n.p.).

Many seemingly extraneous factors can complicate the reading process. First, the presence of metal or water, either in the item itself or in the reading field, can cause significant declines in read rates. This is because liquids absorb radio waves and metal reflects them. Much has been written about the technical problems of dealing with both problems. For instance, when dealing with the tagging of aircraft parts (Wyld, "Soaring Benefits from RFID," 2004) and even luggage tracking (Wyld, "Delta Airlines Tags Baggage with RFID," 2005), the metals present in the aircraft must be taken into consideration. Likewise, there are problems in dealing not just with the presence of water and humidity in the environment, but high water content in the packaging (see "Beware the Wet Cardboard ... and Summers in New Orleans") and in the items being tagged. These include, but by no means are limited to:

- Fruit (Maenza, 2005)
- Beer (Roberti, "The Puzzle of Putting RFID Tags on Beer," 2005)
- Wine (Wyld, "Beyond the Bar Code," 2005)

Any setting in which RFID is used has the potential for radio signal interference to occur. When this happens, the read rates—and therefore the functionality of the system—can be hampered on anything from a minor to catastrophic level. For instance, Douglas Martin, an executive consultant with IBM Global Services, observed that in IBM's work with Wal-Mart on a pilot project involving the back-room grocery operations of seven stores, IBM consultants experienced interference from a number of sources. These included:

- Walkie-talkies
- Forklifts
- Cell phone towers
- Bug zappers (reported in L. Sullivan, "IBM Shares RFID Lessons," 2004).

Likewise, Hewlett-Packard has reported that in some cases, the use of cell phones by their forklift drivers would cause misreads of RFID tags (Albright, "Testing Key to RFID Success," 2005). Finally, there is the simple matter that sometimes the people element comes into play, as workers need to be informed that it is important that they drive the forklift at a certain speed past a certain point or apply a smart label at a precise location on a carton, in order for the RFID tags to be read properly.

Is RFID Safe?

"Can I allow my kids around RFID tags?"

"If Wal-Mart's tagging pallets, is it safe for me to go to my Sam's Wholesale Club?"

"I have a pacemaker. Do I need to watch out for RFID?"

In one form or another, the safety question—will all these radio waves affect the health of me or my family?—surely comes up at any conference or corporate training seminar. The answer is clearly no. Here's the scientific ammo behind that answer:

- 13.56 MHz is between the AM and FM frequencies that have been used for years in commercial radio transmissions, without any known problems. The maximum power level in the United States and most countries is limited to 4 watts.
- 915 MHz is the typical analog cell phone spectrum, and has not been found to cause any health concerns at levels below 1 watt.
- 2.45 GHz is the typical frequency of the newer digital cell phones. At 1 watt or less, there have been no proven health concerns.

In the end, making RFID systems work in practice—meaning produce 100 percent read accuracy—is thus a complex matter. In fact, L. Allen Bennett, the president and CEO of System Concepts, an RFID integrator providing services to the Social Security Administration and other organizations, provided an apt analogy when he stated, "It's a little like Chinese cooking," in that all the ingredients have to be prepared "right" and be combined in the proper manner (quoted in Olsen, 2005, n.p.). Every location where RFID is to be used and every item to be read by RFID thus presents its own unique set of circumstances. Thus, at present, there is no "one best way" to accomplish RFID, whether your setting is a distribution center, an airport, a hospital, a parking lot, or a retail location. Carey Hidaka, an RFID specialist at IBM Global Services, observed that "in many ways, these [RFID] deployments are more art than science, although the science is very important." Hidaka stressed that when working with RFID, it is vital to remember that "these are not plug-and-

Beware the Wet Cardboard ... and Summers in New Orleans

Recent research from the School of Packaging at Michigan State University shows the complexities of how RFID interacts with packaging materials, negatively impacting the readability of RFID tags and labels. The Michigan State researchers, headed by Dr. Robb Clarke, tested how RFID tag readability would be affected by aluminum, cardboard, glass, and even stretch and bubble wrap. For instance, corrugated cardboard is generally seen as a very radio-wave-friendly material. Thus, this ever-present material in shipping and distribution does not detract from tag readability. However, the research team found that once a cardboard container gets wet, the read rates for tags on or in the boxes fell by as much as 50 percent. Even high humidity levels could reduce the ability to successfully read tags by several percentage points. Their findings showed that even after the boxes were apparently dry, the absorptive nature of the cardboard meant that the cartons continued to retain moisture (through a process known as hysteresis), negatively impacting read rates on all subsequent tests (Roberti, "Beware of RFID's Hysteresis Effect," 2005).

This series of tests means that it will be important to monitor RFID-tagged boxes and cartons to see if they encounter moist conditions. It will also mean that companies seeking to use RFID in their supply chain operations in areas that have high humidity (for example, Houston, New Orleans, Atlanta, and Seattle) will need to factor the effects of moisture on tag read rates into their tactical planning for RFID usage.

play systems" (quoted in Albright, "Testing Key to RFID Success," 2005, n.p.).

Conclusion

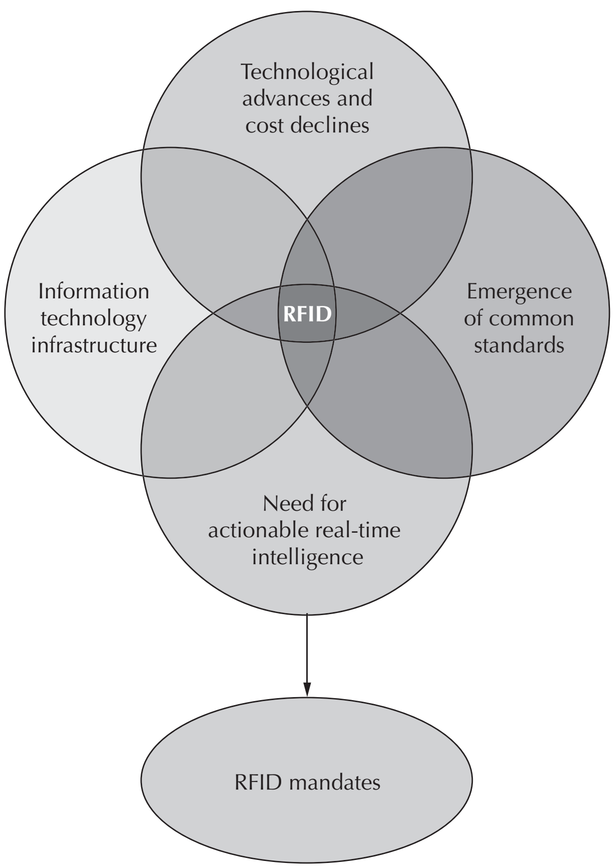
This overview of the fundamentals of RFID has been presented to give the reader a working knowledge of the technology. However, far more information is available for those seeking to learn more about the workings and intricacies of the technology, which are many. Thus, the resources provided in Appendix II are highly recommended for those wanting to pursue RFID in more depth.

RFID and the 'Informationalized' Supply Chain

Introduction: The Fifth Element

As depicted in Figure 5, there are five principal drivers behind the recent upswing of interest—across the American economy and indeed globally—in RFID. First, as we have come to expect with all electronics, the costs and size of the technology have sharply decreased, and concomitantly, its capabilities and applications have rapidly increased. Thus, the increased accessibility of RFID tags and labels have made it possible today to have

Figure 5: Driving Forces Behind RFID



them be used in new, innovative ways. Secondly, emerging open, common standards in RFID technology will enable greater data sharing and collaboration between supply chain partners. Thirdly, with increased competitive pressures and customer expectations, organizations throughout the supply chain need better, actionable information on which to make decisions that can impact successful operations in real time. On a related note, the investments that organizations have made in their IT infrastructures over the past decade now make it possible to capture and use this information. The final reason is simply that leading-edge organizations have recognized these four drivers of RFID technology and created a fifth driver, by mandating its use in their inbound supply chains and seeking to integrate RFID into their internal operations.

Indeed, the push for RFID has been propelled by the mandates that have been issued for the use of the technology in the supply chain. Various retailers, both in the U.S. and abroad, have issued RFID mandates, including:

- Wal-Mart
- Target
- Best Buy
- Albertson's
- Metro (Germany)
- Tesco (United Kingdom)

In contrast to the American approach, which has leading organizations mandating the use of RFID in their supply chains, the European marketplace has indeed seen a more collaborative approach being taken between large retailers and their major suppliers in the case of Metro and Tesco (Goodman, 2005).

'The Wal-Mart Way'

Due to its size and scope, Wal-Mart has been described as the "the 800-pound gorilla of retailing," as it presently has:

- 3,500 stores
- 1.2 million employees
- Sales that account for approximately 2.5 percent of the U.S. Gross National Product (W. Jones, 2005, n.p.).

Wal-Mart's RFID initiative requires its top 100 suppliers to deliver RFID-tagged pallets and cases of goods to select distribution centers in 2005 and its top 200 suppliers to do so by January 2006. Wal-Mart has been described as "the poster child for commercial RFID use" (Morphy, 2005, n.p.).

Indeed, Wal-Mart's mandate will have far-reaching consequences, both for the company itself and for its supply base. Analysts have projected that by implementing RFID, Wal-Mart could reduce its inventory costs by 5 percent and its logistics costs 7.5 percent (Schoettle, 2003). In fact, it has been estimated that Wal-Mart could save as much as $8.35 billion per year in supply chain efficiencies, which is more than the total annual revenue of *half* the companies on the Fortune 500 index (Rush, 2003). With the trickle-down effect, *just* the Wal-Mart mandate will truly have global ramifications across industries. For right now, the participating companies are expending a great deal of time and resources to comply with Wal-Mart's mandate. However, RFID spending amongst the 100 mandatory and 37 volunteer suppliers in the first wave of the Wal-Mart mandate was far from the millions of dollars per firm that had been widely forecast (Boucher-Ferguson, 2005). Indeed, Incucomm (2005) found that the average compliance spending for a Wal-Mart supplier was just under half a million dollars, with the median being less than $200,000.

The Military Mandate

However, it is the U.S. Department of Defense (DoD) that has issued the largest and most sweeping RFID mandate. While the RFID mandates from Wal-Mart, Target, Albertson's, and other retailers will be important, the Defense Department's RFID mandate is far more reaching than that of any retailer, due to the sheer size and scope of the military supply chain. The U.S. military's supply chain is a worldwide operation, which moves almost $29 billion worth of items worldwide each year (cited in L. Sullivan, "RFID Marches Onward," 2005). The military supply chain is not just bullets, bombs, and uniforms, as it involves a wide panoply of goods—the majority of which are consumer goods as well. DoD's directive will ultimately affect approximately 60,000 suppliers, the vast majority of which are not the Lockheeds and Boeings of the world, but small businesses, many of which employ only a few people (Wyld, "Supporting the 'Warfighter' with RFID," 2005). As such, DoD's RFID mandate to have its 60,000 suppliers implement passive RFID by 2007 has been rightly categorized as the likely "tipping point" for widespread use of RFID in supply chains (Roberti, 2003).

The 'Wheelhouse of the Technology'

In the view of Jim Harper, the director of information studies for the Cato Institute, the mandates from large retailers and the U.S. government fall in "the wheelhouse of the technology" to improve the tracking of items as they move through "massive" supply chains (quoted in Baard, "Ridge Says RFID Boosts Security," 2005, n.p.). In this section, we appraise the "informationalized" supply chain and what it will mean for both the procuring organizations and their suppliers. We explore the thinking behind this concept and look at the potential benefits that RFID and increased visibility will bring to supply chain management. We also examine the present state of RFID use amongst suppliers and the challenges they face in complying with these mandates, including the cost of compliance and the challenging data management issues.

The Quest for the 'Perfect' Supply Chain

What if there was a way to uniquely identify *everything?* What if there was a way to track the *history of everything in the supply chain,* just as we do today with shipments of packages by UPS and FedEx? What if you could have information on where something *is*, rather than where it was or where it was intended to be? What if you could have *perfect information?* Is there such a nirvana? Today, that exciting possibility exists with RFID. This prospect led John Hill, a principal with ESYNC, to proclaim that "RFID is the most exciting thing to happen to the supply chain in the last 30 years, *even if it does not work*" (emphasis added) (quoted in *RFID News & Solutions,* 2004, p. R3). It all starts with atoms and bits.

'Atoms' and 'Bits'

Just as over a decade ago we began to link isolated computers via the Internet and vastly expanded the power of the network, we are reaching the juncture where we can "extend the Internet to the physical world" (Walker, 2004, p. 46). We are heading toward what Schoenberger (2002) first described as an "Internet of things." Perhaps more accurately, Professor Rajit Gadh (2004), who heads UCLA's Wireless Internet for Mobile Enterprise Consortium, labeled this a "wireless Internet of artifacts," as this new environment will allow any artifact—even human beings—to essentially become part of the Internet and to eventually be tracked. The mechanism for doing so is RFID.

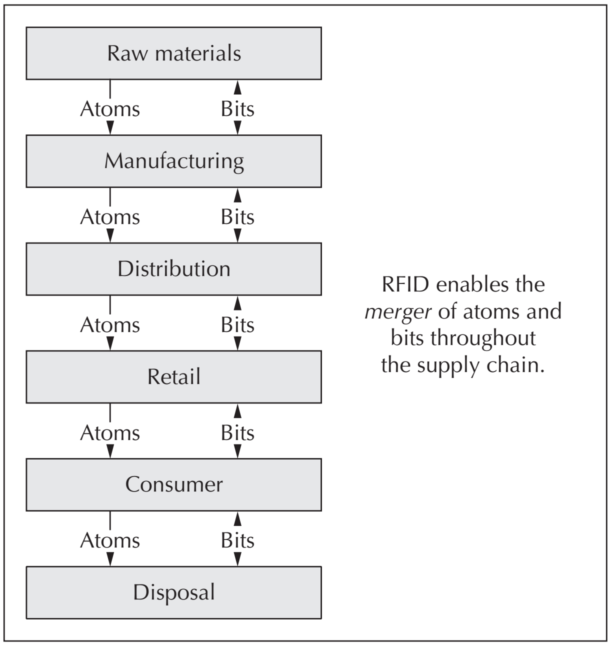
Until now, the focus on supply chain management has been moving atoms—i.e., things—from the producer to the end consumer. Much of this has been done in the absence of real-time information on exactly *what* is occurring in the supply chain. With RFID and automatic identification of items as they move through the supply chain, the process literally does become "informationalized," as bits of information flow to provide the potential for real-time tracking of goods as they move from one stage of the supply chain to the next. As depicted in Figure 6, RFID is an enabling technology to link the object to identifying information about it. As Kevin Ashton, formerly the executive director of the Auto-ID Center at MIT, put it: The vision is for "a world where by moving atoms you can move bits, and by moving bits you can move atoms" (quoted in Roberti, "RFID: From Just-In-Time to Real Time," 2002, n.p.).

Re-engineering a 'Stone-Age Scenario'

RFID plainly has the potential to change the whole manner in which the demand/supply chain works through "informationalizing" the process. Until now, both producers of goods and the organizations that buy them have continued to operate on forecasts—forecasts for production needs on the one end and consumption/sales on the other end. In what Kathuria (2005) described as a "stone-age scenario," manufacturers work off of static, often historical, demand forecasts and hope that their production will be both adequate to meet demand and not so excessive as to produce wasteful product. Purchasers must likewise operate with similar quality information for their procurements. Both have to hope that the *right* product is distributed at the *right* time in the *right* quantity to the *right* location for it to be purchased/used before the shelf life expires. Subtle and/or sudden changes in the demand for an item, either by class or by location, often can't be successfully accommodated by either party, resulting in either a shortage or overage of product availability—to the detriment of both.

Despite significant investments in warehouse management systems, customer relationship management software, and enterprise resource planning, the supply chain of today has been accurately portrayed as being "sloppy and elastic, too often prone to human error" (Lattner, 2004, n.p.). Supply chain work is still complex and labor-intensive, based on

Figure 6: The Big-Picture Context of RFID



Source: *Adapted from Ashton (2003).*

physical scanning, counting, receiving, shipping, and monitoring of things as they move through distribution centers and transportation systems. Despite advancements in technology, processes and people, the management of even relatively simple supply chains means overseeing a process without a great deal of visibility. What is often not discernible—until it is too late—is that the supply process is rife with errors, inaccuracies, and, yes, fraud. It has been shown that retailers and manufacturers each lose $2 million for every $1 billion in sales due to bad data. Simply improving the quality of supply chain data could thus save American firms approximately $10 billion per year (Scheraga, 2003).

RFID and Supply Chain Management

Don Tapscott and David Ticoll (2003), in their book, *The Naked Corporation: How the Age of Transparency Will Revolutionize Business,* placed the push for RFID in supply chain management in the larger context of the push for transparency, both within organizations and between trading partners. They note that the RFID mandates demonstrate a higher level of disciplined commitment to auto-ID technology than was present in the nascent stages of the Internet and the World Wide Web.

Integrating RFID's Capabilities into the Supply Chain

In 1990, Davenport and Short advanced the idea of information technology's role in producing process innovations through better coordination and information access across organizational units. According to Patil (2004), RFID can likewise positively impact a host of organizational and even cross-organizational operations in a number of ways, which are outlined in Table 7. Many of these capabilities are integral to optimizing supply chain management functions.

Shutzberg (2004) observed that RFID is "unlike any technology" that has been available for supply chain management in the past, and while the technology is costly and complicated, "it's inevitable that RFID will be a transformation agent throughout the supply chain" (n.p.). As such, RFID presents great possibilities for organizations to leverage RFID technology to identify individual units in their supply chain. RFID tags or labels can be applied to units moving through the supply chain at various levels. Thus, when we speak of units, it is important to distinguish the category being talked about. Commonly, these are referred to as being item-, case- or carton-, or pallet-level tagging (see Table 8 on page 28).

Table 7: Capabilities of RFID

Capability	Organizational Impact/Benefit
Transactional	RFID can transform unstructured processes into routinized transactions.
Geographical	RFID can transfer information with rapidity and ease across large distances, making processes independent of geography.
Automational	RFID can replace or reduce human labor in a process.
Analytical	RFID can bring complex analytical methods to bear on a process.
Informational	RFID can bring vast amounts of detailed information into a process.
Sequential	RFID can enable changes in the sequence of tasks in a process, often allowing multiple tasks to be worked on simultaneously.
Knowledge management	RFID allows the capture and dissemination of knowledge and expertise to improve the process.
Tracking	RFID allows the detailed tracking of task status, inputs, and outputs.
Disintermediation	RFID can be used to connect two parties within a process that would otherwise communicate through an intermediary (internal or external).
Security/safety	RFID allows an organization to build security and safety into both the process and the product.

Source: *Adapted from Patil (2004, p. 4).*

Table 8: A Schema for the Levels of RFID in Supply Chain Applications

Level	Use	Application
Item	Consumer units	Products and individual items
Case or carton	Traded units	Boxes/packaging/ product carriers
Pallet	Distribution units	Pallets/trucks

Source: *Adapted from d'Hont (2003, p. 13).*

RFID's Value Proposition for the Supply Chain

RFID creates value in two primary ways—lowering costs and providing enhanced visibility. To lower costs, RFID enables the enterprise's supply chain through:

- Better transaction efficiency
- Reducing out-of-stock incidences
- Lowering the shrinkage rate

RFID also lends greater visibility—visibility that can be utilized to better manage assets, items, and people to provide better service delivery.

Singer (2004) recently observed that "RFID's promise of a scan-free supply chain is too attractive to ignore" (n.p.). What are the specific benefits available to organizations that RFID-enable their supply chains? These are summarized in Table 9. According to Haldane and Eischents (2005), an optimized supply chain can bring multifaceted benefits to an organization. These include:

- Increased efficiencies in operations (achieved through improved productivity, increased asset utilization, and more accurate labor management)
- Reduced costs in manufacturing, distribution, and transportation
- Improved customer satisfaction (facilitated by reduced order lead and turnaround times, higher "perfect-order" shipment rates, and more effective communication and collaboration)

Unique identification will mean far greater visibility within the organization, and as supply chain partners and logistics providers also leverage RFID technology, the entire supply chain—from the manufacturer to the distribution center to the shelf to the consumer—can become more visible.

Table 9: Potential Benefits of RFID Implementation in the Supply Chain

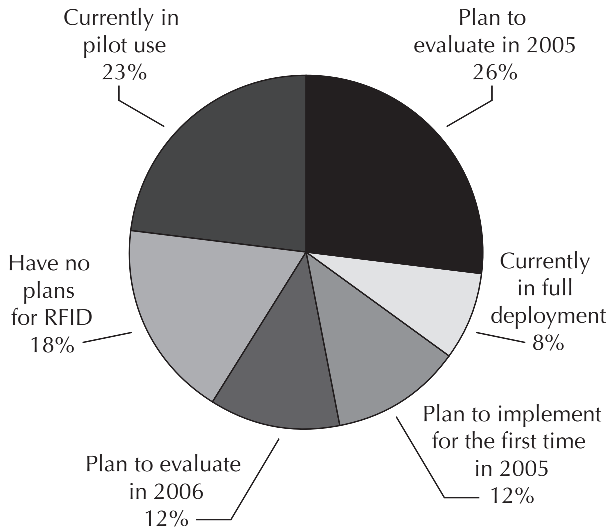
Benefit	Explanation
Counterfeit/ fraud reduction	RFID tag integration can facilitate rapid identification of fraudulent products and enable the tracking of distribution leaks to the black market.
Improved efficiency	RFID permits detection of stock shipments and delivery, allowing customer notification and the introduction of real-time billing.
Labor cost reductions	RFID can remove the need for much of the manual intervention and bar code scanning at distribution points, thereby reducing payroll and management costs.
Returned goods facilitation	Automation of returned goods processes and improved product visibility within the chain can result from RFID product tracking.
Stock shrinkage reduction	Employee theft, inefficient management of stock, and misplaced orders currently account for 2 to 5 percent shrinkage in many supply chains. This factor can be minimized or be avoided after RFID is introduced.
Stocking management improvements	RFID can ensure inventory is replenished before it is fully depleted, resulting in fewer lost sales based on out-of-stock situations.

Source: *Adapted from Landoline (2004).*

Implementing RFID in the Supply Chain

While RFID adoption has not moved as fast as some analysts had originally forecast, a mid-2005 survey of over 500 suppliers, conducted by *RFID Journal* and AMR Research, shows that fully 69 percent of them were in some stage of evaluating, piloting, or implementing RFID in their supply chain operations. As can be seen in Figure 7, only 20 percent of firms were presently *not* looking at RFID (Reilly, 2005).

Figure 7: Status of RFID Technology Deployment



Note: Percentages do not equal 100 due to rounding.

Source: *Adapted from Reilly (2005).*

Bruce Hudson, an analyst with Meta Group, based in Stamford, Connecticut, advised that organizations may be faced with making "a leap of faith" decision to invest today in RFID technology, because at present there is likely not a business case for doing so (quoted in Nash, 2004, n.p.). Indeed, according to a July 2005 survey released by the Warehousing Education and Research Council, fully 55 percent of the supply chain executives surveyed do not believe that they will ultimately see a return on their RFID investments (Anonymous, "ROI on RFID is Not a Sure Bet," 2005). Thus, while many top executives may buy into the vision of an RFID-enabled supply chain, they face a "technological catch-22," due to the long—and tenuous—timeline for a return on their RFID investments. Lacy (2005) described this dilemma by stating: "They're reluctant to spend the money because they think its benefits are a long way off, yet they can never see those benefits if they don't spend the money" (n.p.).

'Slap and Ship'

For many suppliers to Wal-Mart and other mandating companies, as well as the Department of Defense, the approach taken to compliance has been the so-called "slap-and-ship" tactic. With slap-and-ship, the RFID labels are affixed (literally "slapped" in many cases by a human hand or a machine applicator) at the pallet/case levels at the last possible minute, just before the shipment begins its journey to the mandating organization's distribution center.

While slap-and-ship does provide an effective means of compliance, it is an all-cost proposition, with no real upside. From the supplier's perspective then, compliance with the various retailer and Department of Defense mandates can be viewed as a significant tax on the supplying company (Boucher-Ferguson, 2005). Slap-and-ship does not enable the supplier to integrate RFID into its own operations or empower the supplier's network—both upstream and downstream—to enhance the visibility of supply chain movements and possibly derive efficiency and effectiveness benefits from a fuller implementation (Haldane and Eischents, 2005). As such, while slap-and-ship is a cost- and time-minimization strategy for the manufacturers falling within the mandates, it has also been roundly criticized. For instance, from the perspective of Bill Hardgrave of the University of Arkansas' Sam M. Walton School of Business, this makes RFID tags a high-priced—and redundant—substitute for bar codes. According to Professor Hardgrave, "just slapping a tag on the side of a product without changing anything else about how the supply chain is managed will obviously limit its value" (cited in W. Jones, 2005, n.p.). Furthermore, as slap-and-ship solutions are largely not scalable, they may hold a company in place with a "good enough" RFID solution for meeting the letter of the mandates, but retard the firm in developing a longer-term outlook on RFID in its operations (Witty, 2005).

Moradpour (2005) cautioned that while mandates may spur suppliers into action on RFID, "unless the supplier can figure out how this utilization can be leveraged in its business to improve profit and increase capacity utilization, the net benefit to the supplier will be negative" (n.p.). It must be remembered that even "slap-and-ship" solutions can have sizable costs. Fuller RFID implementation comes with a long-term commitment and both sunk and recurring costs. These are summarized in Table 10 on page 30.

Managing—and Using—an 'Avalanche of Data'

As Brewin ("No Silver Bullets," 2005) pointed out, RFID "cannot magically solve supply-chain problems" (n.p.) Indeed, in many instances, the use of

Table 10: Costs Associated with RFID Implementation

Investment Costs	Recurring Costs
Readers (fixed and/or portable)	Tags (single use or reusable)
Antennae	Tag/label application labor
Network/interfaces	Portable reader labor
Middleware/software	Maintenance/upgrade costs
Integration, installation, and training	Ongoing training and development
Labeling/material handling equipment	

RFID "creates a new set of problems," principally in the area of data management.

Dr. Can Saygin is an assistant professor of engineering management and systems engineering at the University of Missouri–Rolla. He is presently working on an RFID data management project, funded by a quarter-million dollar grant from the Air Force Research Laboratory. Dr. Saygin recently observed: "Everybody's putting on those tags because of mandates by the Department of Defense and Wal-Mart, but companies don't know what to do with the data because the tags are going to tell you where they are every split second. If you start storing the data, you're going to need a lot of memory and capability to process the data and make sound decisions" (quoted in Anonymous, "Researchers 'Play Tag' in Unique Auto-ID Testbed," 2005, n.p.).

Indeed, one of the key challenges for all organizations implementing auto-ID technologies will be how to effectively cope with and capitalize upon the wealth of real-time data that RFID will generate. Writing in *CIO Magazine,* Levinson (2003) first warned that organizations will be facing what could be an unmanageable "avalanche of data" when RFID is integrated in their operations. Alvarez ("What's Missing from RFID Tests," 2004) projects that the ultimate impact in most organizations will be somewhere between the current levels of data generated through bar code applications and the "doomsday scenarios" of unmanageable amounts of data. Early RFID technology trials have established that the amount of data generated by pallet, case, and item tracking via RFID tags will be 100 to 1,000 times the volume that companies currently retrieve when using traditional bar coding systems.

How much data? For example, if an organization tags at the pallet or case level, then the amount of data being handled per unit would not change from present levels (i.e., an RFID-tagged pallet would still be counted as a single unit). Likewise, if a pallet contained 32 cases of product, then there would be no difference in the amount of "reads" and the amount of data to be processed and stored. However, whereas the receiver or warehouse worker would have sequentially scanned 32 duplicate bar codes, the nearly instantaneous scan of the pallet would produce 33 unique identifiers, one for each case, plus an additional unique ID for the pallet itself. The only difference in an RFID-enabled versus a bar code environment would be in the number of reads collected, as they would be routinely collected by both fixed and portable readers, as the pallet and cases moved between key points and in stationary inventory checks.

Once an organization decides to tag at the item level, the amount of data to be handled rises exponentially. Take the following example for a single stock keeping unit (SKU) in a single shipment sent to a distribution center. The example is equally applicable whether it is for the blockbuster book *Harry Potter and The Half-Blood Prince,* sent to a Wal-Mart Distribution Center in Robert, Louisiana, or for a book on fighting insurgencies, sent to the Defense Distribution Depot in Warner Robbins, Georgia.

- **SKU:** A single book (1 item)
- **Case:** Holds 30 books (30 x 1 = 30 unique items)
- **Pallet:** Contains 60 cases (60 x 30 cases = 1,800 unique items)
- **Lot:** Contains 20 pallets (20 x 60 cases x 30 books = 36,000 unique items)

During the lot's time at the distribution center, each pallet of goods is scanned approximately 30 times a day, including at its point of receipt, its warehousing location, and its point of shipment. If the RFID network makes 30 unique observations of the lot each day, this means there would be over a million reads—1,080,000 recorded—with each being a unique data point.

Take a major national retailer that decides to tag each item at its outlets as an example. The number of items available in its stores and in its distribution center could easily be in the billions. Let's say that the chain has an average of 10 billion tagged items. The tag identifying the unique items contains 12 bytes of data. Thus, the data generated at any given point in time would amount to 120 gigabytes (10 billion items x 12 bytes of data). If reads were taken every five minutes for 20 hours a day (assuming reads taken during the store's open hours, plus restocking hours), this single company would generate 30 terabytes of tracking data every day (120 gigabytes x 12 reads per hour x 20 hours per day). If 10 leading retail firms all tracked individual items in a similar fashion, they would generate approximately 300 terabytes of data daily. To put this in perspective, this daily data deluge would dwarf the 136 terabytes of data contained in the 17 million books held by the Library of Congress (Bhuptani and Moradpour, 2005).

According to Albright ("Business Intelligence Vendors Sitting Out RFID Rush," 2005), this "highly granular" data will overwhelm most firms' existing data warehouses. For instance, it has been estimated that through RFID, Wal-Mart could be generating more than 7 terabytes of data a day, which Partridge (2004) characterized as a "data tsunami." The real test, from the perspective of Pamela Klym, segment manager for the retail industry at IBM Software, is that "RFID generates an enormous amount of data, but the real challenge is not in generating data, it's in finding a nugget of data and sending it to the right person to act on it" (op. cited in Demery, 2005, n.p.).

Mohsen Moazami, vice president for the Internet Business Solutions Group at Cisco Systems, said that the challenge is to turn the data into "actionable insights" (Moore, 2005, n.p.). With the goal of such actionable intelligence, RFID will place increased importance on processing data closer to the source of the action, rather than transmitting all reads to a central database—which, as has been shown, would quickly overwhelm most corporate systems. Middleware will therefore be key to sorting out the data to be passed on to the organization's central database and to be archived and for how long. However, beyond middleware, there will be a far greater distributed information systems' architecture and an emphasis on what is known as "edge computing" (Levinson, 2003). There will also be a rash of development in what is generally referred to as either "event management" (Trebilcock, 2002) or complex event processing (CEP) software (Marinos, 2005). Such software will automate, to a far greater extent possible, the process of "management by exception." This entails creating a data capture and reporting process to provide context and near real-time operating intelligence to management. Routine exceptions will be increasingly handled through the use of decision agents, pre-programmed to respond to situations where "if A happens, take B actions." Event management software will also function as a monitoring agent to alert managers to truly exceptional occurrences in a process, enabling their intervention earlier in the process than ever before.

A Tool, Not a 'Magic Bullet'

When looking at RFID from a strategic perspective, it is important to be mindful that the technology is not a panacea or magic bullet. From the perspective of Bill Allen of Texas Instruments RFID Systems, RFID should not be looked upon as a cure-all for bad business processes. Indeed, "throwing RFID at the problem" will only exacerbate problems both internally and in a firm's mismanaged supply chain (quoted in *RFID News & Solutions,* 2004, p. R12). RFID is also not always going to be the most suitable, necessary, or, indeed, cost/benefit-effective technology for a given situation.

From the perspective of Cisco Systems' Moazami, "This is an opportunity for business to really rethink business processes" (quoted in Moore, 2005, n.p.). Yet, it is vitally important for all executives dealing with RFID to remember that they should not simply "buy" RFID technology because it is the latest, greatest thing. Indeed Shai Verma, IBM Canada's RFID practice leader, recently observed that RFID "is not a technology play." Rather, Verma advises that organizations should look at how RFID fits into their business (cited in Lahey, 2005, n.p.). In the view of Peter Andrews (2003), writing for the IBM Advanced Business Institute, the fundamental question that all companies and entities looking at automatic identification technology must answer is: *"What is the business problem that I am solving?"* (emphasis added, p. 4).

Fundamentally, RFID should not, in and of itself, be thought of as the "solution." Rather, it is a technology that is a building block that can be used to construct a solution (Haldane and Eischents, 2005). John Clark, Tesco's group technology director, recently commented that it is vitally important to treat RFID as an "ecosystem" (op. cited in Albright, "RFID Worth the Risk," 2005, n.p.). From this perspective, the components of RFID must be carefully worked with in order to make the overall system "work." While most of the pilot and implementation efforts to date have been geared toward the first-order problem of making the readers and tags work together, the most difficult area, according to Cisco Systems' Moazami, will be how to connect all the readers to "the cloud (the enterprise network)" (quoted in Cox, 2005, n.p.).

Conclusion: An RFID Future for Supply Chain Management?

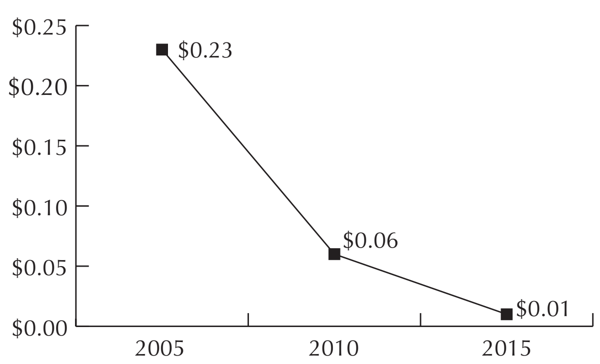
In the end, will RFID replace bar codes entirely in supply chain management over the long term? Will the cost of the technology decline to the point where item-label labeling is ever going to be possible? The "hockey stick" forecasts shown in Figures 8 and 9 are optimistic that this will occur over the next decade.

However, there are many who believe that despite seeing every electronic device in our history become less expensive, even as they grow in power and utility, cheap RFID tags will be unattainable. Kevin Sharp (2002), senior technical editor for *Supply Chain Systems Magazine,* holds that "in a world where paper labels cost three cents each, it's difficult to envision a world where a smart label costs just a nickel" (n.p.). Due to sheer economics, it will not be a viable proposition for a company to individually tag inexpensive items (i.e., a 5-cent tag on a 29-cent candy bar or $1 part). Goodman (2005) framed the issue of tag cost in the following manner: "The discussion about tags coming down in costs is a little bit deceptive. When we arrive at a 5-cent tag—which will eventually happen because of economies of scale—what's that going to do for you? Is that the tag you need to solve your business problem?" (n.p.). Thus, the costs of RFID tags and labels, both presently and in the foreseeable future, will likely preclude widespread adoption on low-margin items.

The cost of the tag in supply chain applications is far less important than whether tagging is taken to the individual-item level. Because when a tag is attached to a pallet, container, bin, or tote, the cost of identifying that unit with a single tag is far less than the cost of identifying each item within that conveyable. Further, with the ability to reuse the conveyance device and the tag associated with it, the multiple uses make the cost of even higher-capacity and wider-range tags economically feasible.

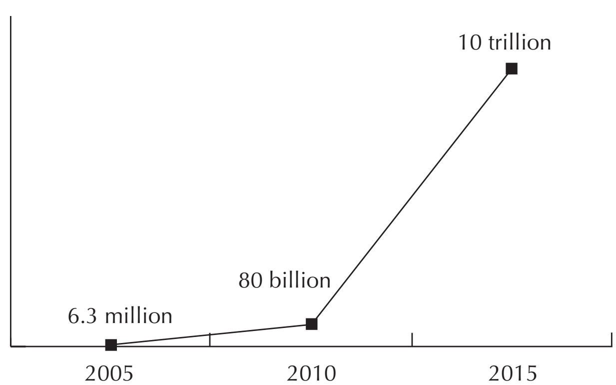
However, there are technological advances on the horizon that may make nickel or even penny tags a reality. The search for a "chipless tag" may not only reduce the cost of RFID tags (as the IC is typically 80 percent of the tag cost), but such research may well come up with alternative technologies that could enhance the performance of RFID tags and overcome some of the "physics problems" inherent with RFID technology. For instance, German polymer researchers are presently working on

Figure 8: Projected Price of RFID Tags, 2005–2015



Source: *IDTechEx (2005).*

Figure 9: Number of RFID Tags in Use, 2005–2015



Source: *IDTechEx (2005).*

mass-producing cheap plastic chips that could be printed on foil, eliminating the need for a silicon-based chip in an RFID tag. According to Wolfgang Mildner, managing director for PolyIC GmbH, a joint venture between Siemens AG and Kurz GmbH KG, his research unit is well on its way to developing an integrated circuit made of polymer that would be suitable for RFID tags, perhaps as early as 2008 (Blau, 2005). Likewise, advances in nanotechnology could lead to not only chipless tags, but also alternatives to the traditional antennas and enhanced memory capacity for tags utilizing nano-size particles (Anonymous, "Nano World," 2005). Also, Surface Acoustic Wave (SAW) technology, which uses the propagation of radio frequency acoustic waves on the surface of polished crystals, holds promise for likewise eliminating the need for integrated circuitry on RFID tags (Bhuptani and Moradpour, 2005).

Writing in *Supply and Demand Chain Executive,* Reese (2005) accurately points out that organizations are not likely to easily abandon decades' worth of investments in technology in bar code technology. In his opinion, the most likely path is that RFID will be a complementary rather than a successor technology to the venerable bar code and the UPC symbol. Thus, what he sees is a hybrid model in which a nesting approach is used. In this scenario, RFID would be used to track pallets and cases of goods, while UPCs would still be used for a long time to come to track individual items on a class, as opposed to a serialized, basis.

In conclusion, Christopher Boone of the analyst firm DC commented: "RFID has the potential to be a revolution in the supply chain, but not yet. Ten years may be a bit aggressive for RFID to be ubiquitous. It will be closer to 15 years—half as much time as it took bar codes" (quoted in Rothfeder, 2004, n.p.).

The Federal Government and RFID in Supply Chain Management

Introduction

Much of the focus in the media and the marketplace has been on the many private sector RFID initiatives. However, the public sector has been an extremely active area of RFID activity in three very different, very prominent supply chains.

This section serves as an introduction to the subsequent three sections, each of which highlights a case study of RFID's application in supply chain management. They are:

- The Department of Defense's supply chain mandate
- The Food and Drug Administration's actions on pharmaceuticals
- The Department of Agriculture's National Animal Identification System program

Malone ("Reconsidering the Role of RFID," 2004) observed that because of their prominence, such large-scale, government-driven initiatives will force early implementation and testing of RFID technology, and, as such, these mandates—or close to mandates—may well serve as the driver that will push the technology of passive RFID.

Department of Defense Case Study Overview

The case study "From Susquehanna to Baghdad: RFID and the Visible Defense Supply Chain" examines the largest supply chain RFID initiative to date—that of the U.S. Department of Defense. We will see that the U.S. military has been at the forefront for using active RFID tagging of containers of goods, vehicles, and equipment. However, DoD has issued the most sweeping mandate of any organization, calling for its 60,000 suppliers to transition to using passive RFID in their military shipments of items of all types by 2007. This ambitious step is being taken as part of an overall strategy to enhance visibility and control over the complex and far-flung supply operations necessary to support the U.S. military's global missions.

This case study (pages 36–43) reviews the background of DoD's mandate and examines the specific steps that will be taken over the next few years to move toward full implementation of the plan. It also examines the potential benefits and challenges that lie ahead, as well as the opportunities presented for the vendor community by the defense mandate. It closes by looking to the possible future state of the technology, where auto-ID could enable true real-time visibility to military commanders.

The Food and Drug Administration and the Pharmaceutical Supply Chain Case Study Overview

The case study "The Right Prescription: RFID and the Pharmaceutical Supply Chain" examines the unique case of the pharmaceutical industry and the plans for implementing RFID technology in its supply chain to a far greater extent than in any other vertical market today. We will see that both the federal government and the states have issued mandates—or what are very close to mandates—to the pharmaceutical companies to begin to use automatic identification technologies to have better control over the prescription drug supply chain. We will see that due to the high monetary value of the product and the absolute need to ensure its integrity and authenticity, the pharmaceutical industry and regulators have both a business case and a security need to have better visibility in the drug supply chain.

This case study (pages 44–50) looks at where we are coming from in terms of today's healthcare industry and the projected costs/benefits of the implementation of this improved—and informationalized—pharmaceutical distribution system. The author shows that industry/government cooperation and educational outreach efforts will be key in making the transition a successful one.

The Department of Agriculture and Animal Identification Case Study Overview

The case study "How Now Brown Cow?: The National Animal Identification System" examines the rationale behind and planning for this soon to be implemented animal-ID program. With the national scope and fast movement of animals and animal food products throughout America—and the importance of export markets to American agriculture—it is essential for animal health officials to be able to have "rapid trace-back" capability. Once the National Animal Identification System (NAIS) is fully implemented, all animals in select species will be identified—largely through RFID technology—and all facilities (or "premises") where such animals are located will be registered with the government. These records, housed in databases maintained by the U.S. Department of Agriculture (USDA) and state/tribal animal agencies, will allow animal health officials, via web-based inquiry systems, to isolate cases of "Mad Cow" and other foreign animal diseases (FADs) within 48 hours of their being reported.

The case study (pages 51–57) outlines the basics of how the NAIS will work and outlines the timeline for the system shifting from one of voluntary compliance to mandatory participation by 2008–2009. It also examines the principal issues that have arisen to date about the NAIS, which center on the following four themes:

- How will agribusiness interests obtain and use the technology?
- Who will bear the costs of implementing the system?
- How will the data be protected and the privacy of the information maintained?
- What are the spin-off benefits to farmers, ranchers, animal marketers, and even abattoirs (processing plants)?

From Susquehanna to Baghdad: RFID and the Visible Defense Supply Chain

Introduction: The 'Tipping Point'

The U.S. military is on the move. While people around the world may disagree on the U.S. military's progress in Iraq, there can be no disputing the advancements that have been made in a massive offensive operation to revamp the military's supply chain. RFID is a key component of this enormous, global effort to lend *visibility* to the worldwide logistics operations of the U.S. military. The goal is to influence the battle through logistics, and in Iraq, we may have well seen the first evidence that RFID can deliver on the battlefield (Roberti, "RFID Aided Marines in Iraq," 2005). This section is a progress report on the efforts, undertaken in a time of war and budgetary challenges, being made to re-engineer the world's largest supply chain in the U.S. Department of Defense, with RFID technology being a key component of the department's overall Total Asset Visibility strategy.

Military logistics *are* fundamentally different from their civilian counterparts. These differences are summarized in Table 11.

While the RFID mandates from Wal-Mart, Target, Albertson's, and other retailers will be important, DoD's RFID mandate has been categorized as the likely "tipping point" for widespread RFID adoption in the United States (Roberti, 2003). The Defense Department's RFID mandate is far more reaching than that of *any* retailer, due to the sheer size and scope of the military supply chain. Estimates are that DoD maintains an aggregate inventory of equipment and supplies totaling more than $80.5 billion (Engels, Koh, Lai, and Schuster, 2004). To facilitate worldwide military operations, Ed Coyle, chief of the DoD Logistics Automatic Identification Technology (AIT) Office, reports that the military moves $28.9 billion worth of items worldwide each year (cited in L. Sullivan, "RFID Marches Onward," 2005). DoD's directive will ultimately affect approximately 60,000 suppliers of all categories of goods shipped to the U.S. military, the vast majority of which employ one to four people (Wyld, "Supporting the 'Warfighter' with RFID," 2005).

A Briefing on the U.S. Military's RFID Strategy

The U.S. Department of Defense has been a leading user of active RFID technology, having employed it to track cargo and equipment shipped to the far-flung theaters of operation for over a decade (Department of Defense, "Radio Frequency Identification [RFID]—FAQs," 2005). DoD began the use of RFID to track equipment and containers being shipped into theaters of operation in the aftermath of the logistical nightmare of men, materials, and equipment that occurred in Operations Desert Shield (1990) and Desert Storm (1991). In every overseas troop deployment that followed, beginning with operations in Haiti and Macedonia, active RFID tagging was used. The percentage of equipment and sustainment stocks that were RFID tagged gradually increased with each successive operation, until it was mandated by the U.S. Central Command (CENTCOM) in 2002:

- 1995: 35 percent in Bosnia
- 1999: 70 percent in Kosovo
- 2001: 85 percent in Operation Enduring Freedom (Afghanistan)
- 2002: 100 percent in Operation Iraqi Freedom (Fee and Schmack, 2005)

Table 11: Differentiating the Military Supply Chain

Readiness	The primary purpose of optimizing the military supply chain is to enhance readiness for war. Knowing the location and status of all materials needed to support operations is an essential component of readiness.
Long supply lines	War is an international activity, which means that lines of supply to support operations are long. Without auto-ID technology that provides real-time visibility of items moving from the suppliers to the frontline troops, it is extremely difficult to maintain accurate knowledge of supply-chain-wide inventories.
Variety of items	Military operations require a large number of items, ranging from everyday supplies to food and clothing to specialized equipment. Different categories of items have different standards for inventory accuracy and visibility.
Unstable demand	Military demand is often variable and unpredictable because conflicts can happen anywhere in the world at any time. When a conflict occurs, demand for supplies increases dramatically and existing stockpiles of materiel are depleted quickly. Accurate inventories are critical to maintaining readiness in the presence of variable demand.
Moving end points	The end, or destination, points of the military supply chain generally move forward with advancing troops and are either terminated or transformed, creating additional difficulties for transportation and inventory management.
Priority	The military supply chain operates on priorities set by unit commanders based on urgency of need.
Equipment reliability and maintenance	Military operations take place in all types of environments and on all kinds of terrain. Under battle conditions, it is important that all identification technologies work effectively and that system maintenance is minimal.
Detection	In a theater of operations, the military must always be careful not to divulge information about its position that would be advantageous to the enemy.

Source: *Adapted from Engels, Koh, Lai, and Schuster (2004, n.p.).*

In the post–September 11 conflicts in Afghanistan and Iraq, massive numbers of vehicles, containers, and bulk items had to be transported from embarkation points in the U.S. to the Middle East and Southwest Asia. Rutner (2004) chronicled how many times transportation officers and commanders were called upon to locate a specific item, part, or vehicle. To do that meant that soldiers/contractors had to take the time to comb through materiel, looking for the proverbial "needle in a haystack" and decreasing the overall efficiency of the transport operations.

On July 30, 2004, the Defense Department outlined its passive RFID mandate, seeking to take "maximum advantage of the inherent life-cycle asset management efficiencies that can be realized with integration of RFID throughout DoD." DoD recognized that RFID could improve visibility in its worldwide logistics operations "to get the customer (in Defense parlance, the 'warfighter') the right materiel, at the right time, and in the right condition" (Department of Defense, "Radio Frequency Identification [RFID]—Policy," 2005).

Visibility is certainly a "buzzword" in military circles today. Assistant Deputy Undersecretary of Defense for Supply Chain Integration Alan Estevez (2005) categorized visibility not as a goal for supply chain management in the military environment, but as a tool—a tool to help:

- Reliably deliver the required item to the right location, in the correct quantity, when it is needed, and from the most appropriate source.
- Make tools and information available to the decision makers who exercise effects-based management of the logistics network.
- Manage end-to-end capacities and available assets, across the supply chain, to best support warfighter requirements.
- Enhance the ability of the supported combatant commander to exercise directive authority over logistics (n.p.).

Transforming the Military for the 21st Century: Alan Estevez, U.S. Department of Defense

By the Partnership for Public Service

On September 28, 2005, Alan Estevez's contributions to government's use of RFID were recognized when he received the National Security Medal, one of the Service to America Medals awarded by the Partnership for Public Service. The following article appears on the Partnership for Public Service website (www.ourpublicservice.org), describing Mr. Estevez's accomplishments at the Department of Defense.

Alan Estevez has an unenviable job. It is his responsibility to develop policies and processes to ensure that the vast quantities of food, fuel, medicine, clothing, munitions, and weapons parts needed to sustain globally deployed U.S. forces are available to them. To do his job, he has to work across the Department of Defense and with 60,000 suppliers of materiel. He has to be absolutely certain that DoD processes ensure every single deployed service member has what he or she needs, when he or she needs it, because otherwise that person's life may be at risk. It might sound impossible, but Estevez has uncovered a key to getting the job done, and his work is transforming military logistics for the 21st century.

To understand the difficulty of Estevez's job, it is important to understand our military history of logistical problems. During Desert Storm, the inability of military commanders to track and locate shipped containers was well-documented, and more than half of the 40,000 cargo containers shipped to the theater, including $2.7 billion worth of spare parts, went unused. The Army estimated that if an effective method for tracking and locating cargo had been in place during Desert Storm, it would have saved them $2 billion.

To determine the most effective ways to improve our military's logistical operations, the Department of Defense looked to the private sector to see how they do business. Alan Estevez, as Assistant Deputy Under Secretary of Defense for Supply Chain Integration, was charged with creating improvements and efficiencies in the military supply chain. Alan saw companies like Wal-Mart looking to use radio frequency identification (RFID) technology to coordinate the flow of goods in and out of their warehouses. He began the development of policies and processes that would require vendors to use this technology when shipping supplies to DoD, thereby bringing the technology being implemented by the world's largest retailer to use for the world's most powerful fighting force.

Alan was also instrumental in the development and deployment of a worldwide RFID infrastructure called the In-Transit Visibility network, which significantly improved the tracking of military supplies. The result of this initiative and other reforms promoted by Estevez has been marked improvements in the efficiency of military logistics and significant savings for our military.

Estevez's technologies are altering the way the Pentagon plans and executes military operations. Critical supplies in the theater can be located and deployed in minutes, as opposed to days during Desert Storm.

Alan Estevez saw that new technologies were changing the way business was done in America, and he was determined to see that our military was not left behind. He met with members of the private sector and helped put the latest technology to work for our armed forces, taking the factory to the foxhole. Estevez is making the seemingly impossible possible, and the result of his work is a more effective and more efficient fighting force.

According to Beizer (2005), DoD's work with active RFID has given the military far better in-transit visibility today than in the Persian Gulf War era. However, the problem was that when supplies reached a distribution depot or port to be disaggregated to the field, the visibility was lost. Thus, the primary challenge was to increase visibility in the so-called "last mile" of the supply chain. With RFID, the U.S. military and its commanders will be able to have near-real-time inventory control throughout the defense supply chain, with worldwide "track and trace" capability. As Estevez (2005) recently wrote: "With RFID, it will be possible to control the supply chain from factory to foxhole and deliver the right item to the right place at the right time, even in the face of rapidly evolving conditions in the battlespace" (n.p.).

The Department of Defense has set an aggressive timetable for implementing its RFID plans. "The Military's Timetable" on page 40 is a summary schedule of the key milestones that are to occur through 2007. As of February 2005, DoD has gone "live" with supplier shipments of four categories of material to two of its distribution centers, located in Susquehanna, Pennsylvania, and San Joaquin, California (Connolly, 2005). In May 2005, Boeing began tagged shipments of aeronautical parts bound for these two depots (Swedberg, "Boeing Tags Shipments to the DOD," 2005). In the view of John Waddick, a program manager for the Army's Joint Automatic Identification Technology Office, the DoD mandate means "there's a lot of tagging that will happen in the next few years. We're going to see tags on everything coming in this country, real-time tracking systems in arsenals and manufacturing facilities, and continued expansion of RFID at the Department of Defense" (quoted in Aitoro, 2005, n.p.).

In late April 2005, almost a year later than expected, the Defense Department issued its proposed DFARS (Defense Federal Acquisition Regulations Supplement) regulations requiring RFID tagging of shipments in the following classes of items:

- Packaged field rations, including Meals Ready to Eat (MREs)
- Clothing and individual equipment
- Tools
- Tents
- Repair parts (Brewin, "Proposed RFID DFARS," 2005).

As of mid-2005, the Department of Defense has issued Blanket Purchase Agreements (BPAs) that extend through June 30, 2007, for RFID tags, fixed and transportable readers, and technical engineering services. As can be seen in Table 12, the companies include both market leaders and a mix of resellers, which include small businesses that under federal contracting laws are allowed a "piece of the action." The military specifications call for readers that can accurately process a minimum of 100 tags per second and tags that will function in a temperature range from -4 to 140 degrees Fahrenheit. Later this year, DoD will issue BPAs for smart label printers and handheld readers (D. Sullivan, "DoD Approves Nine Reader Vendors," 2005).

'Where's the Bullets? Where's the Burgers?'

The keynote speaker at the recent 2005 Department of Defense RFID Summit for Industry, held in Washington, D.C., was Gen. John W. Handy,

Table 12: Department of Defense Blanket Purchase Awards for RFID Technology

Group 1	Group 2	Group 3
EPC Compliant 96-bit Class 1 Tags	**EPC Compliant Multi-Protocol (Class 0 and Class 1) Fixed and Transportable Readers**	**RFID Technical Engineering Services**
Alien Technology Corp.	Alien Technology Corp.	ODIN Technologies
Avery Denison Corp., Security Printing Division	ADT Security Services	Unisys
CDO Technologies, Inc.	CDO Technologies, Inc.	
Intermec	Cheval Rouge	
Lowry Computer Products, Inc.	Intecs International, Inc.	
	Intermec	
	RSI ID Technologies	
	Sys-Tec Corp.	
	WFI Government Services	

Source: *Adapted from D. Sullivan (2005, p. 2;) and Roberti, "DoD Taps ODIN, Unisys for Services," (2005).*

The Military's Timetable

The U.S. Department of Defense has set an aggressive timetable for implementing its RFID plans. Below is a summary schedule of key milestones that are to occur through 2007.

January 1, 2005

RFID tagging was required on individual cases, cases packaged within pallets, and all palletized loads for all new contracts, containing an RFID contract provision, for the following classes of supply:

- Class I Subclass—Packaged Operational Rations
- Class II—Clothing, Individual Equipment, and Tools
- Class VI—Personal Demand Items
- Class IX—Weapon Systems Repair Parts & Components

This date was implemented for commodities to be shipped to two locations:

- Defense Distribution Depot, Susquehanna, Pennsylvania
- Defense Distribution Depot, San Joaquin, California

January 1, 2006

RFID tagging will be required on individual cases, cases packaged within pallets, and all palletized loads for all new contracts, containing an RFID contract provision, for the following classes of supply:

- Class I—Subsistence and Comfort Items
- Class III—Packaged Petroleum, Lubricants, Oils, Preservatives, Chemicals & Additives
- Class IV—Construction & Barrier Equipment
- Class V—Ammunition of All Types
- Class VII—Major End Items
- Class VIII—Pharmaceuticals and Medical Materials

In addition to being required on shipments to the Defense Distribution Depots in Susquehanna and San Joaquin, RFID tagging will be required on these commodity types being shipped to the following 32 locations:

United States Marine Corps

- Marine Corps Maintenance Depot, Albany, Georgia
- Marine Corps Maintenance Depot, Barstow, California

United States Army

- Army Maintenance Depot, Anniston, Alabama
- Army Maintenance Depot, Corpus Christi, Texas
- Army Maintenance Depot, Red River, Texas
- Army Maintenance Depot, Tobyhanna, Pennsylvania

United States Transportation Command

- Air Mobility Command Terminal, Charleston Air Force Base, Charleston, South Carolina
- Air Mobility Command Terminal, Dover Air Force Base, Dover, Delaware
- Air Mobility Command Terminal, Naval Air Station Norfolk, Norfolk, Virginia
- Air Mobility Command Terminal, Travis Air Force Base, Fairfield, California

United States Air Force

- Air Logistics Center, Hill Air Force Base, Ogden, Utah
- Air Logistics Center, Tinker Air Force Base, Oklahoma City, Oklahoma
- Air Logistics Center, Warner Robbins, Georgia

United States Navy

- Naval Aviation Depot, Cherry Point, North Carolina
- Naval Aviation Depot, Jacksonville, Florida
- Naval Aviation Depot North Island, San Diego, California

Defense Logistics Agency

- Defense Distribution Depot, Albany, Georgia
- Defense Distribution Depot, Anniston, Alabama
- Defense Distribution Depot, Barstow, California
- Defense Distribution Depot, Cherry Point, North Carolina
- Defense Distribution Depot, Columbus, Ohio
- Defense Distribution Depot, Corpus Christi, Texas
- Defense Distribution Depot, Hill Air Force Base, Ogden, Utah
- Defense Distribution Depot, Jacksonville, Florida
- Defense Distribution Depot, Tinker Air Force Base, Oklahoma City, Oklahoma
- Defense Distribution Depot, Norfolk, Virginia
- Defense Distribution Depot, Puget Sound, Washington
- Defense Distribution Depot, Red River, Texas
- Defense Distribution Depot, Richmond, Virginia
- Defense Distribution Depot North Island, San Diego, California
- Defense Distribution Depot, Tobyhanna, Pennsylvania
- Defense Distribution Depot, Warner Robbins, Georgia

January 1, 2007

RFID tagging will be required on individual cases, cases packaged within pallets, and all palletized loads for all new contracts, containing an RFID contract provision, for *all* classes of supply shipped to *any* DoD location.

Source: Department of Defense, Office of the Deputy Under Secretary of Defense (2005). "Radio Frequency Identification (RFID)—Supplier Implementation Plan."

commander of the U.S. Transportation Command. General Handy observed that today the U.S. military has become "a world-class deployment organization." He cited the nearly unfathomable logistics operations that have been undertaken by the Defense Department in support of operations in both Afghanistan and Iraq. In fact, as of early 2005, his command has moved over 2 million people since 9/11 to the two theaters of operations. In fact, it has been responsible for shipping:

- 1.2 million short tons of materials
- 62 million barrels of fuel
- 313,000 containers
- 11,280 high-explosive containers
- 140 million meals

To put this in perspective, his staff calculated that this logistics operation is "comparable to taking the entire city of San Antonio, Texas, all the people, all their possessions, and what they need to sustain them, halfway around the world" (quoted in Wyld, "Supporting the 'Warfighter,'" 2005, n.p.)

General Handy commented that in the military community, the focus on logistics transformation has been to create a visible supply chain from the "factory to the foxhole." The foxhole is really an outdated metaphor, as in today's world this means an identifiable, in-theater destination for material, fuel, and supplies. He related a story of how during the fall 2004 campaign to drive the insurgents from Fallujah, the Defense Department's Operations Center actually fielded a phone call from a marine captain in the heat of battle. He called up saying, "We need Hellfire missiles here ASAP. I have an RFID tag here—can I get some?" (quoted in Wyld, "Supporting the 'Warfighter' with RFID," 2005, n.p.). The point of the general's story was that the captain actually had to make the phone call and try to read numbers off the smart label. In DoD's vision of the military of the not-so-distant future, there would be no need for that call, as the resupply of ordnance would have been automatic through a responsive supply effort.

At the same event, Col. Mark Nixon, head of the Logistics Vision and Strategy Center for the U.S. Marine Corps, observed that RFID has enabled a vastly improved logistics effort in Operation Iraqi Freedom over that of the Gulf War a decade ago. In the 1991 conflict, one Marine officer observed that despite stacks and stacks of containers, "We had absolutely no idea where our stuff was." Traditionally, this has led commanders to order parts three, four, or up to a dozen times to ensure the part reaches the necessary unit. Now, with far greater in-transit visibility, there is greater confidence in the distribution system, and by reducing the redundant orders, there have been dramatic cost improvements. More importantly, however, the military's lift capacity is a finite resource. Therefore, eliminating these duplicative efforts reduces strain on the air, land, and sea transport system, and enables a fleeter, more agile military in the field, with the right supplies being delivered to the right place at the right time—all in support of the customer: the warfighter in the field. As Colonel Nixon plainly stated, "The warfighter can influence the battle by having better confidence in the distribution system … allowing him to concentrate on the matters at hand in the battle per se" (cited in Wyld, "Supporting the 'Warfighter,'" 2005, n.p.)

However, current military supply chain operations, while vastly informationalized and improved over that of a decade ago, are still in need of improvement. The Government Accountability Office (GAO) found that there were still severe equipment and materiel backlogs at port facilities and that there was a $1.2 billion shortfall between the amount of materiel shipped to the Iraqi theater of operations and the materiel that was actually received (Gay, 2005). Earlier this year, Col. Glenn W. Walker (2005), writing in the *Army Logistician,* recounted the logistics difficulties of Operation Iraqi Freedom, problems that lasted far past the invasion and fall of Saddam Hussein. Colonel Walker commented that the immaturity of RFID technology and the lack of RFID infrastructure and formal procedures demonstrated that "adding technology without first implementing the right organizational and doctrinal changes only means that we know more quickly that we're in trouble—and we have no way to fix it" (n.p.).

However, as the Department of Defense moves toward its plans for extensive item-level tagging by 2007, the benefits are becoming clear. As Fred Naigle of the Army's Joint Automatic Identification Technology office recently commented, "If it currently takes 20 days to send something from San Joaquin, California, to troops in Iraq, and the military is able to cut three days off the delivery cycle, we can create visibility and shrink the pipeline" (quoted in L. Sullivan, "RFID Marches Onward," 2005, n.p.). And, while some may tout RFID as enhancing a firm's competitive advantage, it is important to remember that the military's competitive advantage comes from having the right personnel, equipment, and supplies where they are needed anywhere around the globe.

A principal challenge that is proving critical in the actual implementation of RFID in the military supply chain is read rates. As has been the case in commercial applications, DoD has experienced significant problems achieving a high percentage of correct reads from passive tags/labels. As reported by Brewin ("No Silver Bullets," 2005), read rates have been in the 80 percent range for tests run in diverse locations around the defense supply network, from the Naval Supply Systems Command's Navy Ocean Terminal in Norfolk to Defense Logistics Agency depots in Susquehanna and San Joaquin to Air Force operations at Ramstein Air Base in Germany. These tests have meant that human counts have had to be used to supplement the auto-ID methods and that RFID is not acceptable for transactions of record at this point for payment purposes. However, they have also shown that simple modifications (such as adding or repositioning readers) and training (such as how to optimally place tags, stack cases, and approach reading portals) can significantly enhance read rates.

The Defense Driver

According to Mike Liard, a senior RFID analyst at Venture Development Corporation, the military will ultimately face almost incalculable costs in deploying RFID. This is because the necessary infrastructure for equipping just one warehouse could run as high as half a million dollars; therefore, the Defense Department could easily spend perhaps tens of millions of dollars to properly RFID-enable just a single depot (opinion cited in Brewin, "Army Raises RFID Spending Cap," 2004).

The DoD mandate thus presents both a fundamental proving ground for RFID technology on a worldwide basis, as well as monumental opportunities for RFID vendors. As Cliff Horowitz, CEO of Samsys Technologies, recently remarked: "The Department of Defense has enormous warehouses with a total of tens of thousands of dock doors, and eventually every one of those doors is going to need a fixed RFID reader" (cited in D. Sullivan, 2005, p. 3). Additionally, with the breadth of items that will fall under DoD's RFID mandate, many of which are consumer products, tagging will extend far beyond anything being contemplated by the Wal-Marts, Targets, and Metros of the world.

According to the analyst firm INPUT, federal spending on RFID technology is expected to grow 120 percent by fiscal year 2009 (Anonymous, 2005, "Federal RFID Spending to Rise 120%"). This spending on RFID hardware, software, and services will be driven by the Defense Department. The CEO of ChainLink Research, Ann Grackin, has estimated that DoD spending alone on RFID will rise from $150 million–$200 million for 2005 to $500 million–$700 million in 2007 (cited in L. Sullivan, "RFID Marches Onward," 2005). And for the military, unlike for most supply chain applications today, there does appear to be an ROI with RFID. According to Estevez, the Department of Defense expects a $70 million payback on its RFID investment over the next three years, not taking into account the potential for reducing inventory stockpiles and the increased readiness of weapons systems (cited in Albright, "RFID Worth the Risk," 2005).

The Future?

Writing in the *Army Logistician,* Fee and Schmack (2005) recently remarked: "The lessons learned from Operation Enduring Freedom and Operation Iraqi Freedom show that the best we can expect from the current RFID capability, as technically efficient as it is, is to know where supplies and equipment were, not where they are" (n.p.). On a final note, then, one of the exciting areas for research and development activity will be how to combine RFID technology with sensing capabilities and other technologies in the military supply chain. Such R&D will certainly have corollary benefits in commercial supply chain applications and will likely produce derivative technologies as well.

One of the most promising examples of such research is the recent proof-of-concept trial conducted by the Defense Logistics Agency (DLA) of active RFID tags that combine RFID technology with satellite communications to enable tracking to a precise location, even in the most distant and inhospitable conditions. In January 2005, four pallets were equipped with a prototype tag—dubbed the Third-Generation Radio Frequency Identification with Satellite Communications (3G RFID w/ SATCOM) tag—at the Defense Distribution Depot in Susquehanna. The four pallets and their destinations were as follows:

- Kuwait: camouflage netting
- Tikrit, Iraq: automobile engines
- Kandahar, Afghanistan: vehicle-repair kits and Humvee radiators
- Bosnia and Kosovo: mixed freight

With the use of GPS technology and the ability to communicate via the Iridium global satellite network, the pallets could be tracked on a constant basis, within a range of approximately a yard. While it has been forecast that it will be a couple of years before such tags could be put in widespread use, the results of the test show the power of real-time visibility. According to the DLA, such visibility "will change the DoD's RFID network from providing information on where shipments of equipment have been and closer to a real-time understanding of where that equipment actually is" (quoted in Collins, 2005, "DOD Tries Tags That Phone Home," n.p.).

The Right Prescription: RFID and the Pharmaceutical Supply Chain

Introduction: Defining 'Mission Critical'

If a child receives a defective video game or action figure, the problem can be easily remedied by a return visit to the retail outlet. However, if the prescription antibiotic given to a child has been altered, mishandled, or is not genuine, the consequences could be grave.

In general, companies think of their line of business as having a "mission critical" supply chain. However, the pharmaceutical industry is unique in that its products are literally a "life or death" matter. If a specific drug is not available at a given hospital at the precise moment a patient needs it, the consequences can be fatal. Likewise, if a patient is given a prescription drug that is counterfeit, out of date, or mislabeled, the individual can experience dire consequences, which are often extensive and expensive—and perhaps fatal. Every year in the U.S., approximately 100,000 people die from medical errors, with 7,000 dying just due to drug interactions arising out of the over 3 billion prescriptions dispensed annually (Schoenberger, 2003).

In this section, we look at how the pharmaceutical industry in the United States is setting the pace for applying RFID technology to product tracking. We begin with an overview of the American healthcare industry and the significant role that prescription drugs play in healthcare delivery—and costs—in the U.S. We then examine the major drivers for RFID implementation in the pharmaceutical supply chain, along with some lessons learned and early return on investment perspectives from first movers in the industry. Finally, we look to the future with some projections for when widespread tracking of prescription drugs will be in place and what the benefits will be not only for pharmaceutical companies, but also the providers of care and their patients.

The Big Business of Healthcare in the United States

Despite the "whiz bang" technology that we see in use at American health clinics and the computer systems in place in both hospital and retail pharmacies, the healthcare industry overall has been slow to adopt new technology. In a March 2005 cover story, *Business Week* focused on "The Digital Hospital" as the U.S. healthcare industry begins to focus anew on technology as a means of promoting cost-effective, high-quality health services. This new tech focus is being brought about both by government policies and by competitive pressures, as, more and more, consumers have more choices in accessing healthcare services and employers are demanding better value and quality for rising healthcare costs (Mullaney and Weintraub, 2005).

According to the most recent statistics available, healthcare presently makes up 15 percent of the total U.S. economy—a staggering $1.7 trillion. According to projections from the Centers for Medicare & Medicaid Services (CMS), the unit of the federal government that is the chief compiler of healthcare data, a decade from now this figure could more than double, to reach $3.6 trillion by 2014. Healthcare spending would represent 19 percent of the American economy, with the government picking up an increasing share of this spending. This would mean that in 2014, the U.S.—which already spends more on healthcare than any other nation on the planet—would be spending over $11,000 for the health needs of every man, woman, and child (Appleby, 2005).

The U.S. share of the global pharmaceutical market has risen dramatically since 1992, when American consumption represented approximately one-third of the world market. Last year, Americans spent $231 billion for prescription drugs. This represented 8 cents out of every healthcare dollar (see Figure 10). As demonstrated in a recent report from IMS Health (2005), pharmaceuticals play a prominent role in American healthcare, more so than in any other nation. As can be seen in Figure 11, the North American market accounted for 47 percent of the global prescription drug market, which exceeded half a trillion dollars in 2004.

The reasons for the growth of the prescription drug market in the U.S. are manifold, and they include:

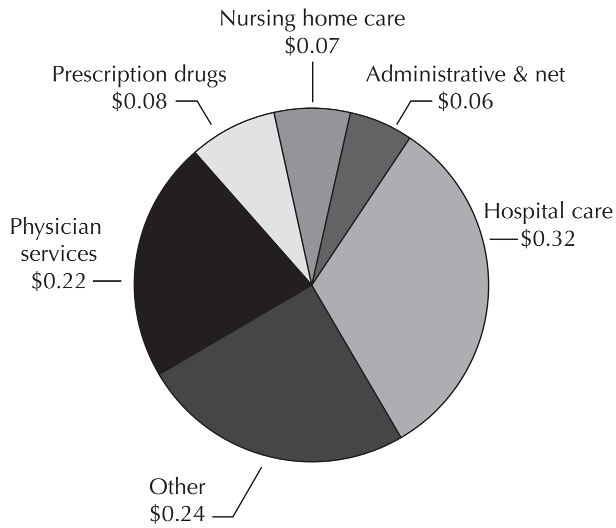
- Economic growth
- High employment
- Aging population
- Pricing freedom
- Government and insurer reimbursement (Class, 2002)

It is noteworthy that direct-to-consumer advertising is a significant driver of the American pharmaceutical market as well, as this somewhat still controversial practice allows for consumer demand for newer, more targeted, and efficacious—if not cost-effective—treatments for everything from cardiovascular disease and diabetes to Attention Deficit Hyperactivity Disorder and erectile dysfunction.

With a new prescription drug plan for senior citizens in the process of taking effect, the federal government will be paying for markedly more of the nation's pharmaceuticals than it has historically. According to CMS projections, Medicare's share of national spending on prescription medications will rise from just 2 percent in 2004 to 28 percent of the bill in 2006 (Appleby, 2005). Dr. Mark McClellan, chief administrator of the Medicare program, believes that RFID is part of the overall emphasis on finding new ways to creatively and effectively apply new healthcare technologies. According to Dr. McClellan, "We're trying to create the business case for more coordinated, efficient care, and inevitably that means more investment in tech" (quoted in Mullaney and Weintraub, 2005, n.p.).

The pharmaceutical market is propelled by blockbuster drugs, driven by the fact that today it takes well over half a billion dollars to get a new pharmaceutical product to market. As such, pharmaceutical companies now spend approximately 20 percent of their revenue on research and development, aimed primarily at finding the next "big thing" (Pharmaceutical Researchers and Manufacturers Association, 2001). There is also significant market

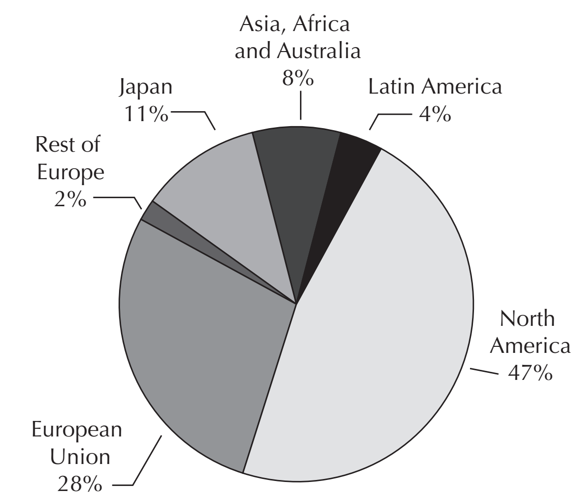
Figure 10: Breakdown of U.S. Healthcare Spending



Note: Amounts do not equal $1.00 due to rounding.

Source: *Centers for Medicare and Medicaid Services, Office of the Actuary, National Health Statistics Group, 2004.*

Figure 11: World Pharmaceutical Sales, 2004



Source: *IMS Health (2005).*

concentration with leading firms and their "star" products. In fact, the 10 leading prescription drug products account for over a third of all pharmaceutical sales worldwide (see Table 13). Also, after a decade of mega mergers in the global pharmaceutical market, the top 10 companies today control approximately half of the prescription drug market (see Table 14).

With the United States being by far the largest market for prescription medications and American firms playing a leading role in an increasingly consolidated and "high stakes" pharmaceutical market, the U.S. market will be the determinant of how RFID can and should be implemented in the pharmaceutical supply chain.

The 'Drug Pushers'

Three primary drivers are propelling the use of RFID in the prescription drug supply network in the United States:

- The federal government
- The state of Florida
- Wal-Mart

Table 13: Top 10 Pharmaceutical Products, 2004 Global Sales

Rank	Product	2004 Sales (in billions of U.S. $)	Growth Rate (constant U.S. $)
1	Lipitor	$12.0	+13.8%
2	Zocor	5.9	-6.4
3	Plavix	5.0	31.4
4	Nexium	4.8	25.3
5	Zyprexa	4.8	-3.5
6	Norvasc	4.8	1.2
7	Seretide/Advair	4.7	22.5
8	Erypo (Eprex/Procrit)	4.0	-4.1
9	Ogastro/Prevacid	3.8	-3.5
10	Effexor	3.7	20.1
	Total sales of top 10 products	**$53.6 billion**	**+8.6%**

Source: *IMS Health (2005).*

Table 14: Top 10 Pharmaceutical Companies Ranked by Product Sales, 2004

Rank	Company
1	Pfizer
2	GlaxoSmithKline
3	Merck & Co
4	Sanofi-Aventis
5	AstraZeneca
6	Novartis
7	Johnson & Johnson
8	Bristol-Myers Squibb
9	Wyeth
10	Abbott

Source: *IMS Health (2005).*

The Federal Government

The U.S. government has long been active in attempting to provide for the integrity of the drug supply. While concerns heightened in the wake of September 11, in truth, the federal government has been quite active in such efforts since the Tylenol poisonings of the 1980s. At present, the U.S. Food and Drug Administration (FDA) (2004a) is especially concerned with acting to prevent counterfeit drugs from entering the nation's drug supply.

Drug counterfeiting is not as common in the United States as in other areas of the world, such as Africa, where as much as half the stock of certain classes of pharmaceuticals have been found to be counterfeit. While it has been estimated that counterfeit drugs represent less than 1 percent of the total U.S. pharmaceutical product supply, counterfeit drug cases have been steadily on the rise in the U.S. since 2000 (U.S. FDA, 2004a). The increase has been attributed to several factors, including:

- The growing number of high-demand, expensive drugs
- An abundance of small wholesalers buying and selling medication
- The increasing sophistication in forgers' capabilities to produce fake labels and packaging (Appleby, 2004).

The FDA now fears that such criminal enterprises will become ever more sophisticated in their capabilities to produce drugs that visibly appear to be the same as name-brand pharmaceuticals, but that have been contaminated and/or have only inactive or incorrect, sub-potent or super-potent ingredients. In recent years, U.S. authorities have seen several high-profile drug forgery cases, such as the following:

- Fake Lipitor pills
- Vials labeled as Procrit that were only filled with water
- Aspirin that had been substituted in bottles for the schizophrenia treatment Zyprexa (Appleby, 2004).

The FDA sees counterfeit drugs as one of today's most pressing public health and safety concerns. Accordingly, in a February 2004 policy statement, the FDA (2004a) advised that "use of mass serialization to uniquely identify all drug products intended for use in the United States is the single most powerful tool available to secure the U.S. drug supply" (n.p.) The FDA recommended that the pharmaceutical industry move to implement RFID tagging throughout the supply chain for controlled substances by 2007. While at present the FDA has not moved to mandate the use of RFID at the individual-item level, it is strongly encouraging all participants in the drug supply chain to cooperatively work to make this possible. To that end, in November 2004, the FDA (2004b), wanting to keep the agency's oversight function to a minimum, issued a directive that allowed pharmaceutical companies to implement RFID labeling and product tracking without having to first gain approval from the agency.

The State of Florida

In June 2006, a new drug pedigree law will take effect in the state of Florida. As of that date, drug producers and wholesalers in the pharmaceutical supply chain will have to be able to electronically track the chain of custody of all controlled substances being shipped to the state. If supply chain partners cannot or choose not to comply with the Florida drug pedigree regulations, they face substantial financial penalties (Skrinar, 2005). Thus, this state's unilateral action is likely to have widespread impact across the American pharmaceutical market, as other states—and perhaps even the federal government—will likely look to Florida as a benchmark for the shift to tighter control over the drug supply. RFID appears to be the *only* technology that will allow for companies to effectively comply with the state law.

Wal-Mart

The final driver for RFID adoption in the pharmaceutical industry is the entity that is driving much of the wider push for auto-ID technology—Wal-Mart. While its actions in the pharmaceutical area have attracted far less press and attention than the firm's mandates with its top suppliers, Wal-Mart quietly announced in November 2003 that it would require its suppliers of Class II narcotics to apply RFID tags at the warehouse pack level—essentially a master bottle for a pharmacy (Walker, 2004).

The Wal-Mart Class II narcotic mandate has spurred innovation in the pharmaceutical industry. In November 2004, the Stamford, Connecticut–based Purdue Pharma, the maker of OxyContin, a painkiller that has the dubious distinction of being the most stolen and counterfeited drug, became the first company to comply with this branch of the Wal-Mart mandate (Sliwa, "Suppliers Eye RFID Data," 2005). Purdue Pharma has begun a major RFID implementation effort throughout its supply chain, looking to integrate the technology throughout its supply chain and in working with its distribution network. David Richinger, executive director for package design and development for Purdue Pharma, commented: "Long term, we think RFID is the right approach for product authentication and creation of an electronic pedigree throughout the supply chain. There are significant benefits in our industry to identifying product from the point of manufacture to the retail pharmacy. And we're very interested in working with the wholesalers and retailers to make the information visible up and down the supply chain" (quoted in Roberti, "Purdue Pharma Gets Down to the Item," 2005, p. 20). Purdue Pharma is even donating 100 RFID reader devices to law enforcement agencies around the country for use in reading bottles of suspect OxyContin that come into their possession (Appleby, 2004).

The Right Prescription

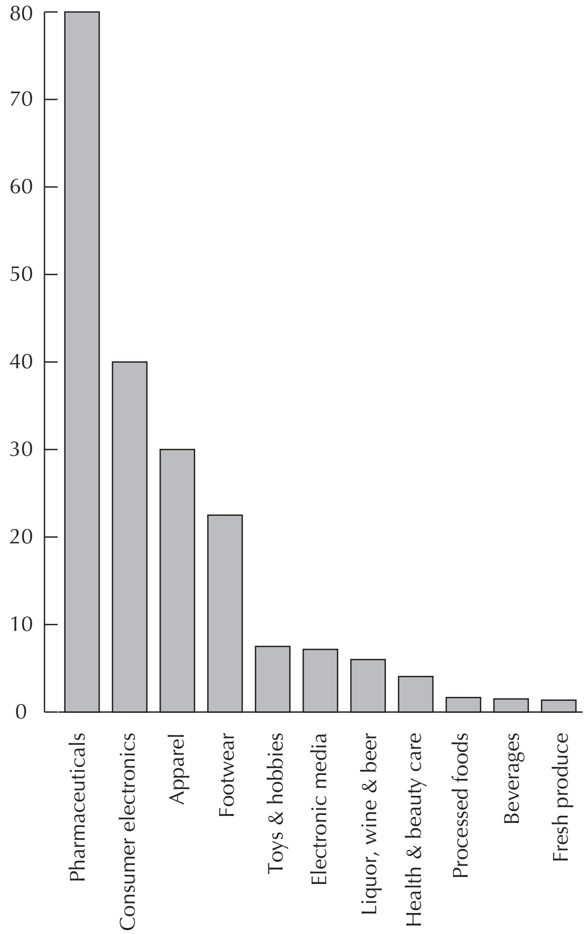
While many initiatives are under way at present to initiate the use of RFID at the pallet and case level in supply chain management, the pharmaceutical industry appears to be the leading candidate for RFID tagging to be expanded to the individual-item level. As can be seen in Figure 12, the high relative value of pharmaceutical products relative to the price associated with RFID-equipped labels means that from an economic perspective, prescription drugs would be the most likely product to be individually tagged. According to a special report on RFID for *Pharmaceutical Business Strategies,* item-level identification is crucial due to the unique needs of the drug industry, including:

- **Pedigree reporting:** to be able to track pharmaceuticals from factory to pharmacy—and, perhaps, to patient.
- **Cold chain management:** to verify the proper transport of temperature-sensitive pharmaceuticals.
- **Anti-counterfeiting:** to reduce the opportunity for counterfeit product to enter the medical delivery system at any point.
- **Anti-diversion:** to gain better control and visibility of the pharmaceutical supply chain to diminish the possibility for drugs to be redirected away from their intended destination (Anonymous, "RFID Solutions for Pharmaceuticals," 2005).

The "track and trace" capabilities for tracking individual package forms of pharmaceuticals would facilitate product recalls, allowing for drug manufacturers, wholesalers, and retailers, as well as healthcare facilities, to quickly locate suspect bottles or packages from specific lots or production runs. Item-level tagging would also allow for better stock management in a pharmacy or warehouse, providing management the ability to pinpoint specific packages of a pharmaceutical that was at or past its expiration date.

The counterfeit drug threat appears to be at the forefront of concern of both the government and manufacturers. Several major drug companies have made recent announcements that they will begin item-level tagging of their pharmaceutical products that are highly valued, with strong, legitimate demand—

Figure 12: RFID Ratio of Margin to Tag Cost for Various Products



Source: *Adapted from Hintlian and Proud (2004, p.177).*

and highly suspect to threats of counterfeiting, diversion, and theft. These include:

- **Pfizer—**which says it will ship Viagra by the end of 2005 with RFID chips embedded in packaging (Brewin, "RFID Gets FDA Push," 2004).
- **GlaxoSmithKline—**which says it will begin tagging its Retrovir and Epivir drugs (used to treat AIDS and HIV infection) within the next 18 months (Brewin, "Medicines to Get RFID Tags," 2004).

Pfizer selected to tag Viagra specifically due to its high consumer demand and high counterfeit susceptibility. According to Pfizer Vice-President Tom McPhillips, "Drug counterfeiting is a serious and growing problem, and RFID offers the potential to be an important anti-counterfeiting technology in the future." However, McPhillips added that RFID "is certainly not the only solution" (Pfizer, 2004, n.p.). To that end, his firm is instituting changes aimed at disabling counterfeiters' ability to precisely copy Viagra's packaging. Pfizer is also looking to make changes to state pharmaceutical regulations to push for more stringent licensing of pharmaceutical wholesalers, and to lobby for increased legal action in the U.S. and abroad against Internet sellers of illegal versions of Viagra (Pfizer, 2004).

"Smart shelves" that manage stock and automate the replenishment and product rotation processes can have a significant benefit in the pharmaceutical area. Smart shelves will also enable a facility to have systematic recording of any unusual activity in its pharmaceutical supplies, alerting administrators to possible theft or unauthorized removals of controlled substances. Likewise, reordering can be made automatic when the supply of any drug reaches a set minimum stock. And, considering that smart shelves would be used in controlled areas, away from patients in a healthcare setting and customers in a retail pharmacy, they would not raise the privacy issues that would be found in similar uses in the retail environment.

Finally, a significant part of the promotional efforts of pharmaceutical companies comes in the form of distributing free samples of prescription drugs to physicians. The doctors, in turn, distribute these sample products to their patients for their initial use of a drug or for a "trial offer" of a medication. In all, according to the most recent data available, out of the $21 billion that was spent on promotional efforts by pharmaceutical companies in 2002, $12 billion came in the form of promotional samples. This represents a significant increase, as just two years earlier, less than $8 billion in product samples were distributed, with no sign of the uptrend lessening (McQuivey and Feehan, 2005). Drug companies, however, have very little control over how, when, where, and to whom the samples are distributed, giving them very poor visibility on their returns from this significant marketing investment. Moreover, because the product is distributed outside of the normal drug supply chain, the pharmaceutical companies have a significant exposure to potential liability if expired or contaminated drugs are given to patients. Finally, there is anecdotal evidence that theft is a significant problem with samples, especially with lifestyle drugs such as Levitra, Cialis, and Viagra.

Summary: The RFID Rx

Malone stated that "it does not take a rocket scientist to discover that pharmaceuticals are a prime candidate for the use of RFID in our new era of high security" ("Reconsidering the Role of RFID," 2004, n.p.). As we have seen, the pharmaceutical supply chain, both in the U.S. and abroad, is about to undergo dramatic change as auto-ID technologies are implemented over the next five to 10 years. Indeed, the use of RFID with controlled substances will likely be one of the vanguard areas for auto-ID applications. Moving forward, the pharmaceutical industry will set many of the early best practices and lessons learned—both on the positive and negative side of the equation (Wyld, "The Smart Pill," 2005).

However, regarding the ROI prospects for any RFID implementation, it is important to be mindful, as Christine Spivey Overby, an RFID analyst with Forrester Research, recently commented, that: "There's no question that the benefits are back-loaded and the costs are front-loaded" (op. cited in Schuman, 2004, n.p.). Thus, even in the pharmaceutical area, where the costs and benefits can be measured in life and death terms, the business case must be made for RFID, and ROI considerations must be factored into these decisions. Unquestionably, the push for RFID will mean substantial investments in auto-ID technologies throughout the pharmaceutical supply chain, including upgrading the IT operations of drug manufacturers and distributors to manage and utilize the data flow that will come from this enhanced product visibility. Likewise, according to recent analysis from the FDA (2004b), the nation's 34,000 chain-owned pharmacies will need to install 170,000 readers over the next few years to track RFID-tagged controlled substances.

It will be especially important for *all* actors in the pharmaceutical supply chain to foster participation in RFID, as well as communication between system partners, to make the RFID prescription work. Pharmaceutical manufacturers, distributors, and retailers, along with healthcare executives and practitioners, should work together to set industry-wide standards that will facilitate the use of auto-ID to improve the efficiency, visibility, and quality of the prescription drug supply chain. Lastly, it will be especially important for patients and consumers to be made aware of the ongoing progress in the use of RFID in the drug supply chain. Public relations and consumer education will be key, so that accurate information can be provided to the end users of pharmaceuticals and the inevitable "urban legends" that will accompany item-level tagging ("The government will know the instant I take a drug in my own home!") can be counteracted. In the end, RFID is likely the right prescription for pharmaceuticals, and it will be fascinating to see pills become "smart."

How Now Brown Cow?: The National Animal Identification System

Introduction: 'Mad Cow'

Two words inspire fear in every non-vegetarian in America: "Mad Cow." While the disease is formally known as Bovine Spongiform Encephalopathy (BSE) in cattle and as variant Creutzfeldt-Jakob disease in humans, mad cow disease is scary precisely because it is always fatal. In fact, mad cow has killed approximately 150 people worldwide, mostly in a particularly gruesome outbreak in Britain in the 1990s. Mad cow also inspires fear in every person employed, both directly and indirectly, in the American beef industry. And those numbers are sizable. According to research from Iowa State University, the American beef industry employs over a million and a half workers and generates over $68 billion in annual sales (Lawrence and Otto, 2003).

When the U.S. suffered its first case of mad cow disease in December 2003, billions of dollars were lost as American consumers decreased—at least temporarily—their appetite for beef products. This sparked an economic wave that rippled through the restaurant, grocery, and consumer products industries. The case also led dozens of countries around the world to ban the importation of beef from the U.S.; Japan, once the biggest import market for U.S. beef, has yet to lift its ban (Anonymous, "U.S. Checking for Possible Case of Mad Cow Disease," 2005). In the summer of 2005, cattlemen, ranchers, beef processors, and even the wait staff at every steakhouse in America—from Shula's to Sizzler—were bracing for the impact of this second American case of mad cow, found in a cow in Texas (Kaufman, 2005). The ripple effects are likely to once again be significant throughout the U.S. economy as, more and more, beef will not be "what's for dinner" on American tables.

This section examines a major effort being undertaken by the federal government, in conjunction with leading agribusiness interests in the U.S., to protect the safety of the animal supply chain and the health of American consumers as well as the health of the American beef, poultry, swine, and other animal-based industries. First, we examine the importance of animal identification and provide a brief history of such efforts in the U.S. Then, we detail the National Animal Identification System, or NAIS, which, for the first time, will enable animals to be tracked to the specific location where they are—and, importantly, where they have been and with which other animals they may have been in contact. The NAIS will enable animal health officials, via the Internet, to have heretofore impossible rapid "trace-back capabilities" in the event of an outbreak of a serious animal disease such as mad cow (Wyld, "'Mad Cow' Policy," 2005).

We discuss the mechanics of how the NAIS will work and the timeline for its implementation. We also look at the practical issues of how farmers, ranchers, and animal marketers will use and pay for the technology. The section concludes with a look ahead to 2008 and 2009, when the NAIS is intended to shift from a voluntary program to a mandatory system, involving hundreds of millions of animals annually and hundreds of thousands of locations in the animal supply chain. Additional information on NAIS is available at www.usda.gov/nais.

The Need for Animal Identification

In the U.S., well before the 2003 mad cow case, the agriculture industry and the government—both at the federal and state levels—recognized the need for uniquely identifying animals. Since the 1940s, the U.S. Department of Agriculture has had a cattle identification program in place to confirm each cow's vaccination for brucellosis. Since 2001, it has also instituted the National Scrapie Eradication Program, to counter this malady in the sheep and goat population (USDA-APHIS, 2005a).

Several industry-specific associations have also had successful animal ID programs in place to identify and provide pedigree information on animals in their species. For instance, the American dairy cattle industry has had a voluntary registration program in operation for over three decades. The Dairy Herd Improvement Association (DHIA) presently has over half of all dairy cattle identified in its database. However, the DHIA program is not comprehensive, in that it can locate a dairy cow in its current location, but it cannot track an individual cow's movements over its lifetime (Fourdraine, 2005). Likewise, industries where animals are raced or shown, such as horses, dogs, and cats, have had successful ID systems in place for some time as well.

Because these programs have been industry specific and largely voluntary, there has not been a "national standard" for animal identification systems for all animals of any species, let alone multiple species, with a common set of data standards and programs. Indeed, in the case of cattle, one cow may presently have up to five separate identifying numbers and even identifying marks/methods for a variety of different programs and purposes, including herd management, disease eradication, and sales/commerce (USDA-APHIS, 2005b). However, none of the existing industry or government programs extends the visibility necessary to enable the rapid trace-back capabilities necessary to quickly contain an outbreak of contagious disease in the animal population, which is critical in today's mobile—and national—agricultural system and food supply chain.

The push for a national automatic identification system for cattle and other livestock in the United States began in 2002, with the forming of the National Institute for Animal Agriculture (NIAA). The NIAA represented a combined effort of industry, government (both state and federal), and animal health professionals. This group prepared what became known as the United States Animal Identification Plan (USAIP) (National Institute for Animal Agriculture, National Identification Development Team, 2003). This draft plan was released at the annual conference of the United States Animal Health Association (USAHA) in October 2003, and it was well received by both the agriculture industry and the USDA (Wyld, "Where's the Beef," 2004). In fact, many of the core concepts and key technical aspects of the USAIP have been incorporated into the USDA's National Animal Identification System.

The National Animal Identification System (NAIS)

Today, animals and animal-based products move rapidly in the American economy. Take the beef industry, for example, and consider that:

- On average, each of the 93 million cows in America change ownership three and a half times over their lifetime, ending with the meat packer (Swedberg, "Cattle Auctioneer Promotes Tracking Plan," 2005).
- In a single year, cattle from 40 states and several foreign countries enter the state of California (Natzke and Johnson, 2003).
- Wal-Mart is the world's largest beef retailer. If meat product from a BSE-infected cow were to be shipped by a processor to one of its regional distribution centers, it could literally be in the hands of consumers within a matter of days (Wyld, "Where's the Beef," 2004).

Thus, a serious cattle-borne disease epidemic could literally spread from coast to coast quite quickly, without better means of identification and isolation than are present today.

According to USDA's Animal and Plant Health Inspection Service (APHIS) (2005c), the goal of the National Animal Identification System is "to be able to identify all animals and premises that have had contact with a foreign or domestic animal disease of concern within 48 hours after discovery" (n.p.). This 48-hour trace-back capability is vital to contain and eradicate the disease by limiting the scope of any outbreak and minimizing damage to the affected animals, the agricultural interests involved, the American economy, and the population as a whole. The NAIS will enable animal health officials to trace a sick animal or group of animals back to the herd or premise that is the most likely source of infection. Not only can these animals be identified, but the NAIS will be able to locate animals that may have been exposed to the suspects animal(s) while they were at the premises where the identified infected animal(s) were, even if they have moved on to a new owner or new location, or even been processed for food. As USDA officials plainly addressed the matter: "The sooner animal health officials can identify infected and exposed animals and premises, the sooner they can contain the disease and stop its spread" (USDA-APHIS, 2005e, n.p.). The species to be covered by the NAIS are listed in Table 15.

Three key elements are necessary to achieve the 48-hour trace-back capability:

- Premises registration
- Animal identification
- Animal tracking

Table 15: Animal Species to Be Identified Through the National Animal Identification System

Species
Camelids (llamas and alpacas)
Cattle and bison
Cervids (deer and elk)
Equines
Goats
Poultry
Sheep
Swine

Source: *U.S. Department of Agriculture, Animal and Plant Health Inspection Service.*

Premises Registration

The first stage of the NAIS will be to identify all locations where animals are managed, held, or passed through. These are known as "premises," and they encompass *any* location where animals can commingle. Thus, for the purposes of the NAIS, all of the following locations are examples of premises:

- Farms
- Ranches
- Grazing areas
- Veterinary clinics
- Animal exhibition centers
- Livestock markets and auctions
- Slaughter and processing establishments (USDA-APHIS, 2005d)

Each of these premises will be identified with a seven-character identifier—a Premises Identification Number (PIN).

According to the NAIS, each premises will be issued a single PIN, regardless of the number of animals located there or the variety of species that may be at that premise. States and Indian tribes will take the lead role in registering premises in their jurisdiction. This process began in August 2004. According to the USDA, as of June 2005, 47 states and five Indian tribes have established premises registration programs. Over 79,000 premises have been registered nationally, with over 10,000 in the state of Wisconsin alone (Anonymous, "Press Release: USDA Extends Comment Period for Animal Identification Strategic Plan," 2005).

The states and tribes can use a web-based system for registering premises in their area, provided by APHIS and housed in Fort Collins, Colorado. The governments, however, may elect to create and maintain their own databases for registering their premises, as long as their system meets minimum national standards. The PIN will thus serve as a pointer to information on the specific location associated with it. This data will be stored in the National Premises Information Repository, a national database that will have 12 specific data elements on each "premises" in the country (USDA-APHIS, 2005d). These are set forth in Table 16 on page 54.

If a premise is sold, it will maintain its unique PIN, and the information on each premise in the national database will be maintained for 20 years. This means that data can be gathered on locations even after they may no longer be used for agribusiness purposes (USDA-APHIS, 2005f).

Table 16: Premises Data to Be Stored in the National Premises Information Repository

Item	Content
1	Premises ID number
2	Name of entity
3	Owner or appropriate contact person*
4	Street address
5	City
6	State
7	Zip/postal code
8	Contact phone number
9	Operation type (e.g., production unit, exhibition, veterinary clinic)
10	Date activated
11	Date retired (e.g., date operation is sold, date operation is no longer maintaining livestock)
12	Reason retired

Source: *U.S. Department of Agriculture, Animal and Plant Health Inspection Service.*

Animal Identification

The second element of the NAIS will be a national "one number—one animal" identification system for all animals in species covered by the plan that may commingle with animals from other sources in their lifetime. In time, this single number—the AIN, or Animal Identification Number—will replace the multiple identifiers animals such as cattle and hogs have had for differing purposes. In simple terms, the AIN will become the animal equivalent of the Vehicle Identification Number, or VIN. The format for the AIN will be 15 numeric characters, as shown in Figure 13. For animals that typically move as groups from birth throughout their lifespan, such as chickens and swine, those who oversee them can obtain a Group/lot Identification Number, or GIN.

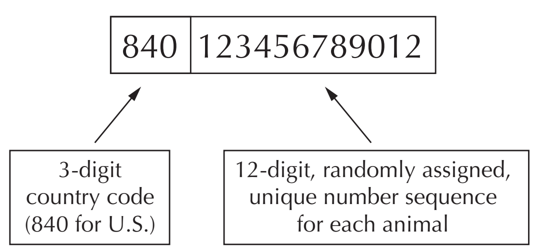
The AINs and GINs will be issued by the states and by tribal authorities through officially designated number management offices. Under the NAIS framework, once animal producers/managers/exhibitors register their premises, they should obtain AINs/GINs for the animals housed there. Once the NAIS is fully implemented, AINs/GINs will be issued to animals as soon as practicable after their birth to allow for tracking over their lifetime (USDA-APHIS, 2005b). If an animal is imported into the United States, that animal (or group/lot) will need to have an AIN/GIN issued to it (USDA-APHIS, 2005g).

What means will be used to identify the animal and its AIN? Will it be RFID, or will it be other high-tech methods, such as retinal scanning or even DNA testing? Could it be the old-fashioned branding method? The USDA's position is to remain technology neutral and concentrate on designing the overall identification data system. In its official statements, the department believes that the market will dictate what ID method will be appropriate for specific species, stating that "there is no 'one-size-fits-all' identification technology" (USDA-APHIS, 2005h, n.p.). Indeed, while RFID-equipped ear tags or implanted devices may be the obvious choice for larger animal species, such as cattle, bison, camelids, and cervids, for other smaller animals, such as goats, the size of their ears may preclude such tagging methods (USDA-APHIS, 2005g). Fourdraine's (2005) research clearly demonstrates that at least for the cattle industry, RFID ear tags will be the most cost-effective way to track individual cows and herds as they move from location to location. Indeed, Dale Blasi, an industry expert at Kansas State University, says RFID will eventually be used to track every domesticated animal in the United States (opinion cited in Anonymous, "Can RFID Protect the Beef Supply?" 2004, n.p.).

Animal Tracking

Once the premises registration and animal identification elements are in place, animal health officials will be able to track an individual animal's movements over its lifetime, as it moves from premises

Figure 13: Sample 15-Digit Animal Identification Number (AIN)



Source: *U.S. Department of Agriculture, Animal and Plant Health Inspection Service.*

to premises. In the case of animals commonly housed in groups, the movements of the group/lot can be tracked in the same manner, but without the automation possible with the "one animal—one number" system. The prescribed protocol, according to the program standards for the NAIS, will have the receiver of the animal (or group/lot) reporting receipt of the animal to the National Animal Records Repository and/or the appropriate state/tribal agency. In the case of abattoirs, or processing plant operators, they would be required to report both the receipt of the animal and the slaughter of the animal (USDA-APHIS, 2005f).

The USDA has set forth a timeline for implementation of the NAIS. The key benchmarks in this timeline are outlined in Table 17.

The National Animal Identification System is to be a voluntary program—for now. While the secretary of agriculture, under the powers granted to the office by the Animal Health Protection Act (AHPA), could institute such a system unilaterally, the USDA is committed to both public and industry input into the NAIS plan and to allowing for a phased-in implementation of the program. This is being done both to garner support for the program and to allow for any kinks to be worked out as the program is being implemented. Yet, the paradoxical situation is that for the national identification system to be effective, there needs to be complete visibility across all premises and in all affected species. Thus, it is inevitable that the program be made mandatory in the U.S. Such an approach that begins on a voluntary basis, followed by mandatory participation, has been taken in other countries, such as Australia, Brazil, and Canada, where national animal ID frameworks are presently in place (USDA-APHIS, 2005f).

Table 17: Timeline for Implementation of the National Animal Identification System (NAIS)

Date	Milestone
July 2005	All states capable of premises registration
July 2005	Animal Identification Number system became operational
April 2007	Premises registration and animal identification "alerts" issued
January 2008	Premises registration and animal identification required
January 2009	• The entire NAIS program becomes mandatory • Reporting of defined animal movements required

Source: *U.S. Department of Agriculture, Animal and Plant Health Inspection Service.*

As can be seen in the timeline (Table 17), the USDA is planning for the transition to making the NAIS mandatory, with premises registration and animal identification being required in January 2008 and the tracking of animal movements beginning in January 2009. The USDA is publicly committed to going through the normal federal rule-making channels to do so. However, the department is hoping that "market forces" will encourage early participation in the program by stakeholders in the agriculture markets, due to the benefits to the respective animal industries of better assurance of animal health and the continued marketability of their animals and products. USDA is also counting on decision makers in the agribusiness industry to decide to "voluntarily" enroll their premises and tag the animals in order to "beat the rush" when such practices will be made mandatory (USDA-APHIS, 2005g). The success of this adoption strategy can only be judged over the long term.

Key Issues Involved with the National Animal Identification System

Agricultural interests and policy makers have several important areas of concern with the NAIS program. These generally fall into the following four areas:

- Technology
- Costs
- Data privacy
- Spin-off benefits

Technology

One of the key concerns in implementing the NAIS is the availability of tagging technology throughout the agricultural marketing chain. The USDA recognizes that there are many ranches, farms, and marketing facilities that will not wish to invest in the technology necessary to tag and monitor their stock. Thus, the department is specifically allowing for animals to be transported without having been issued an AIN to what will be known as “tagging stations.” These stations will—for a fee—apply the necessary tagging device to an animal and report that animal’s information to the central animal information repository. These stations may be specialized fixed facilities, set up to exclusively provide this tagging service, or they may be an established entity, such as a veterinary clinic, livestock marketing facility, or fairground/exhibition hall. However, all such tagging stations will need to be licensed and approved by the state government or tribal authority in their jurisdiction (USDA-APHIS, 2005g).

Finally, for owners of animals that would never leave a premises (i.e., a personal horse), the NAIS does not require them to be identified. However, the USDA will encourage that these animals be tagged, because foreign animal diseases can be transmitted even when animals do not commingle or leave their home premises. Examples of serious animal diseases that can be transmitted in this manner include:

- West Nile virus
- Foot-and-mouth disease
- Vesicular stomatitis
- Equine infectious anemia (USDA-APHIS, 2005h).

Costs

The projected costs of the NAIS are substantial. It has been estimated that the cost to create the system by 2009 will exceed half a billion dollars, with recurring expenses for RFID tags and software/hardware upgrades to be in the range of $70 million to $122 million annually (Olsen, 2004).

To date, the federal government has not shown a willingness to bear a significant share of the overall cost of the program. In fact, it has spent just over $50 million on the development and implementation of the NAIS to date (Reed, 2004). The USDA believes that because of the benefits in protecting the animal population from disease, and protecting the agricultural markets from the shock that can occur when such outbreaks take place, the costs of the program should be borne by the industry. However, consumers could well end up bearing the costs of enhanced animal identification in the form of higher prices for meat, poultry, and other animal products. Yet, if events happen that would raise the fear that animal disease outbreaks could be intentionally started as acts of “agroterrorism,” then it is likely that the federal government would step in to substantially fund the NAIS as a way of enhancing homeland security (Wyld, “Where’s the Beef,” 2004).

Data Privacy

One of the vagaries of the American system is the public availability of government information. Because the National Animal Identification System will store data on federal databases, the information could be made available upon request to interested parties through the Freedom of Information Act (FOIA). Thus, the USDA recognizes that it has a conundrum in trying to protect this information. According to Undersecretary of Agriculture Bill Hawks, “It is our intent for this information to be available only for various animal health officials, whether it’s state officials or federal animal health officials, to carry on their disease control work” (quoted in Olsen, 2004, n.p.). The USDA is assuring those in the animal industry that the national repositories will include information for animal and disease tracking purposes only. As such, any proprietary information and/or production data will not be reported through the NAIS, remaining in private databases (USDA-APHIS, 2005g). However, states like Wisconsin that are looking to make the NAIS mandatory are incorporating privacy into the legislation (Fourdraine, 2005). Likewise, the USDA is actively pursuing specific legislation that would exempt the NAIS from the scope of FOIA (USDA-APHIS, 2005h).

Spin-Off Benefits

In the end, one of the principal considerations in the development of this first national standard for animal identification is the advancement of information technology in the agribusiness area. In many ways, the discussions regarding animal identification mirror the discussions among suppliers who face complying with the RFID mandates of Wal-Mart, Target, Tesco, and the Department of Defense. If the various players in the animal industry, in effect, adopt a slap-and-ship strategy, and do not seek to integrate the benefits of the tagging technology into their own operations, then the animal identification mandate will be all costs, with no upside. However, just as with product suppliers (Kevan, 2005), the sooner the tag is applied to an animal—whether at the ranch, the exhibition, the stockyard, or, yes, the abattoir—the more opportunity there is to use that increased visibility and enhanced information to manage the operation. Fourdraine (2005) has projected in detail the potential benefits for the management of dairy herds. Also, the switch to a single identifier, especially for cattle, will likely prove to be a significant efficiency move, enabling ranchers, animal marketers, and processors to deal with much cleaner data sets.

Conclusion

Today, it appears that the National Animal Identification System is well on its way to becoming an integral part of American agriculture. For the beef industry and for other parts of the animal supply chain, this appears to be a matter of "when" and not "if," although it remains to be seen if the program will be made mandatory throughout all animal species presently covered by the plan. However, the stakes for American agriculture are such that it would appear to be very much in the interests of all stakeholders—government, industry, and the public at large—for such a system to be put in place as soon as possible. As we have seen with past animal disease outbreaks, the costs—both in terms of animal and human lives and in terms of the impact on agricultural interests—are too great not to have such a rapid trace-back capability in place. As Representative Michael Rogers (R-Ala.), a member of the House Agriculture Committee's Livestock and Horticulture Subcommittee, commented: "If we have a foot-and-mouth outbreak, everyone will be clamoring to figure out what went wrong. We'll all be sitting around saying 'I wish we would have done this.'" (quoted in Reed, 2004, n.p.).

As the NAIS moves toward full implementation, all actors in the agricultural marketing system, and in the wider food supply chain—both in retail/wholesale distribution and in the restaurant industry/institutional food services area—should carefully monitor its progress and the implications for their respective businesses. It is likely that as with other areas of the economy, such as the retail, pharmaceutical, aeronautical, and defense supply chains, the introduction of RFID technology and the improved visibility that can be gained through the linking of disparate databases and ID systems through automation will present agribusiness interests—from the farmer and rancher on Main Street to corporate executives on Wall Street—with opportunities to improve their business processes and enhance food safety in the process.

An RFID Agenda for Government

Introduction: Nearing Take-Off

"Here's the real lesson learned: the technology works."

> Alan Estevez, Assistant Deputy Undersecretary for Supply Chain Integration for the Department of Defense (quoted in Albright, 2005, "RFID Worth the Risk" emphasis added, n.p.).

At this early stage in the use of RFID technology, there are far more questions than answers, far more pilots than implementations, and far more interested observers than users of RFID. Indeed, we are early on in the lifespan of RFID technology. In fact, many leading industry experts expect full-fledged implementation of RFID to take 10 to 15 years or more (Emigh, 2004). Amar Singh, vice president of SAP's Global RFID Initiative, observed that, at present, no one knows the true and lasting impact of *RFID* on the overall business of companies simply because "no one has done it yet" (cited in *RFID News & Solutions,* 2004, p. R8). Susan Griffin of Juniper Research summed up the situation: "The take-off point is likely to come at the end of 2006 and through 2007 as tag prices fall and more and more companies see the return on investment possibility of deploying RFID" (quoted in Collins, "EU RFID Spending to Near $1.9 Billion," 2005, n.p.).

However, there are several areas where government can aid in the progress of the RFID revolution. These are in the areas of:

- RFID best practices
- Standards for RFID technology
- Research on RFID technology
- Education on RFID technology
- Privacy-related RFID issues

In many instances, these efforts should be, by design, joint undertakings by the public and private sectors, since it may be hard to separate the visible hand of government from the invisible hand of the economy in regards to many aspects and applications of this technology. In select countries abroad, as outlined in "Foreign Governments and RFID Initiatives/Funding" on pages 60–61, national and even provincial governments are taking an even more direct role in the promotion of RFID technology.

RFID Best Practices

If we look at what is necessary for RFID to be tried, tested, and evaluated in the public sector, the primary need is for executive leadership. Champions must emerge at all levels of government who are willing to set a path toward RFID. Perhaps the greatest function that the public sector can serve is that of a testing ground for RFID technologies, and champions need to emerge who are willing to evaluate whether the technology can improve their operations.

One example of such a champion can be found at the federal level. On December 6, 2004, G. Martin Wagner, associate administrator for the Office of Governmentwide Policy for the General Services Administration (GSA), issued a directive on RFID. In it, the GSA recognized the potential of RFID to improve the visibility and control over both the management of assets and supply chain management. The GSA directed federal agency heads to examine how RFID technology could be used in one or more of the following areas:

- A *receipt function* to automatically update inventory and valuation
- A *storage and issuing function* to include inventory management
- A *transportation function* to include the movement and consolidation for transshipment
- A *maintenance function* to track equipment needing preventative maintenance, calibration, and so on, and assembly or disassembly
- A *disposal function* to track the disposition of property including the tracking of hazardous materials (emphasis added) (GSA, Office of Governmentwide Policy, 2004, p. 2).

In May 2005, the Government Accountability Office (U.S. GAO, 2005) issued a survey of RFID interest and use across the federal sector, looking for planned and pilot uses beyond the Department of Defense. GAO found 28 planned or active RFID projects across 15 cabinet-level agencies. This survey simply sought to establish the level of interest in RFID across federal agencies. The findings are summarized in Table 18 on page 62.

Social Security Administration

One example of a successful RFID program beyond DoD in the federal government is that of the Social Security Administration (SSA), which has been a progressive federal agency in the use of RFID. SSA piloted RFID in 2003 in its internal office supply store, individually tagging items and issuing RFID-enabled shopping cards to allow for automatic reconciliation of “shopping” activity. In the store operations, tagged items could be scanned at checkout, and the system provided greater inventory accuracy and enabled automatic reordering (Albright, 2004). SSA now has also implemented RFID in its warehouse management (for such items as forms, flyers, and supplies). In the warehouse operations:

- 98 percent of orders are now processed within eight hours.
- Order processing time has been reduced from 45 days to three.
- Order backlogs have been eliminated.
- Picking (pulling items for shipment) has increased from 500 lines per day to 1,500.
- Fill rates of 94 percent on normal orders and 98 percent on emergency orders have been accomplished, both with minimal safety stock.
- The agency has been able to reduce its warehouse space by 60,000 square feet through inventory optimization.
- Annual savings of more than $700,000 per year have been realized (Anonymous, “Social Security RFID,” 2005; Olsen, 2005).

Finally, SSA has employed RFID for fleet management of an 86-vehicle pool, which receives over a thousand use requests monthly. The system employed RFID for key-management systems, and it provided greater availability of pool vehicles while making for cost-operational efficiencies (Burnell, 2004).

‘Critical Thing’ Tracking in Government

Public sector users have demonstrated that RFID can improve the tracking of both critical things and even critical people. In the former category are several exemplary public sector examples of RFID pilots and implementations that have already taken place. These include:

- Library materials
- Court documents and evidence
- Hazardous waste

Libraries

Libraries have been at the vanguard of implementing RFID-based tracking, inventory, and checkout systems. For instance, in Virginia Beach, Virginia, the public library system is investing $1.5 million in an RFID-based inventory system and placing tags (at a cost of 50 cents each) in each of approximately 800,000 items at nine library locations (Sternstein, “Virginia Beach Sees RFID Payoff,” 2005). Likewise, in suburban Frisco, Texas, the library system is outfitting its libraries with a similar RFID-based tracking system (Anonymous, “Frisco Public Library Deploys RFID Technology,” 2005).

Foreign Governments and RFID Initiatives/Funding

Outside of the United States, other national and territorial governments are taking an even more direct role in the promotion of RFID technology. For instance:

United Kingdom. In March 2000, the UK's Home Office launched the Chipping of Goods Initiative. The goal of the project was to leverage the investment of £5.5m (or approximately US $8.8 million at the time) in public funding, in order to demonstrate how theft could be reduced in the retail supply chain through the use of RFID technologies. The project sought to show how RFID could reduce property crime, and, in the process, reduce the strain on police resources in combating such crime and in attempting to reunite items with their proper owners (U.K. Home Office, 2003). John Denham, the UK's crime reduction minister, commented that "as criminals are using increasingly sophisticated methods, so we must harness the latest technology available to us if we are to catch them" (quoted in Clark, 2002, n.p.). The private sector partners selected for the project almost doubled the UK government's funding for the project, bringing the total investment in the Chipping of Goods Initiative to

Project	Private Sector Partners	URL for Case Study
Boats	• HPI • British Marine Federation	http://www.chippingofgoods.org.uk/download/casestudies/boats.pdf
Wines and spirits	• Allied Domecq • De La Rue • CHEP	http://www.chippingofgoods.org.uk/download/casestudies/winesandspirits.pdf
Jewelry	• Argos	http://www.chippingofgoods.org.uk/download/casestudies/jewellery.pdf
Personal care products	• Unilever • Tibbett & Britten • Safeway	http://www.chippingofgoods.org.uk/download/casestudies/personalcare.pdf
Fast-moving consumer goods	• Woolworth's	http://www.chippingofgoods.org.uk/download/casestudies/consumerproducts.pdf
Laptop computers	• Dell • BT	http://www.chippingofgoods.org.uk/download/casestudies/laptopcomputers.pdf
Compact discs	• e.centre • EMI • Handleman • Asda	http://www.chippingofgoods.org.uk/download/casestudies/compactdiscs.pdf
Mobile phones	• TRI-MEX International • DHL • Nokia	http://www.chippingofgoods.org.uk/download/casestudies/mobilephones.pdf

Source: *U.K. Home Office (2003). "Chipping of Goods Case Studies." Retrieved from the web on October 19, 2004. Available at http://www.chippingofgoods.org.uk/casestudies.htm.*

£15m (AIM Global, 2003). The eight demonstration projects of the initiative were in the areas outlined below. Roberti's "The U.K. Chips In" (2002) analysis of the initiative was that beyond its stated goals, the real aim of the UK government was to "seed the market" for RFID and encourage British firms to be at the forefront of adopting and capitalizing on the technology. In 2002, Roberti predicted that this would be a wise investment of public dollars, rather than a simple subsidy of large firms' technology projects. His prediction has proven correct, as a recent analysis of the European market for RFID points to the Chipping of Goods Initiative as the catalyst that helped propel the UK to the forefront of the European market (Collins, "EU RFID Spending to Near $1.9 Billion," 2005).

South Korea. In June 2005, the government of South Korea announced its intent to invest approximately $800 million between 2005 and 2010 in RFID research and development efforts. Among other projects, the Korean government is financing the construction and operation of an RFID center in the northern city of Songdo. South Korean Minister of Information and Communication Daeje Chin recently talked about the strategic importance of his government's taking a leading role in RFID technology. Minister Chin stated: "This [RFID] will be very important for us in the next 10 years. The handset business is very big, but RFID will be as important. We are trying to procure a number of goals with RFID, and the application of new technology brings benefits in all social systems including the individual family" (quoted in Ilett, 2005, n.p.).

Victoria, Australia. The Australian state of Victoria is seeking to establish the region as a leader in RFID technology. The state established the VicRFID cluster in August 2004 as a public/private effort to foster research, development, and deployment of RFID technology. In July 2005, the state government announced the broadening of the VicRFID cluster to become the RFID Association of Australia, a move to enlarge the group's reach while retaining its focus on economic and technological development in its home region. At the same time, Victoria also announced that it would be establishing a permanent exhibition center in Port Melbourne to showcase the state's RFID capabilities. According to Marsha Thomson, Victoria's minister for information and communication technology, the aim is to "cement Victoria as an RFID hotspot" (cited in Anonymous, "Victoria Eager to Become RFID Hotspot," 2005, n.p.).

Scotland. The government of Scotland's principal economic development authority, Scottish Enterprise, opened the Wireless Innovation Demonstration Lab at the Hillington Park Innovation Centre in Glasgow. According to Ian Downie, who directs the lab, the goals for the operation, which is funded entirely by the Scottish government, are to educate Scottish enterprises on RFID technology and to enable them to develop business relationships with RFID vendors. Already, leading firms, such as Symbol Technologies, Sun Microsystems, and IBM, have contributed hardware and software to the operation and have begun working with Scottish firms on RFID applications. The Wireless Innovation Demonstration Lab has already enabled a Scotland-based software firm, Spartan Solutions, to partner with Sun on an RFID project (O'Connor, "Scotland Provides RFID Support," 2005).

Table 18: Federal Agencies' Reported or Planned Use of RFID Technology

Agency	Application
Department of Agriculture	• Animal identification program
Department of Defense	• Logistics support • Tracking shipments
Department of Energy	• Detection of prohibited articles • Tracking the movement of materials
Department of Health and Human Services	• Physical access control
Department of Homeland Security	• Border control • Immigration and customs (U.S. Visitor and Immigrant, Status Indicator Technology [US VISIT]) • Location system • Smart containers • Tracking and identification of assets • Tracking and identification for use in monitoring weapons • Tracking and identification of baggage on flights
Department of Labor	• Tracking and locating case files
Department of State	• Electronic passport
Department of Transportation	• Electronic screening
Department of the Treasury	• Physical and logical access control • Records management (tracking documents)
Department of Veterans Affairs	• Audible prescription reading • Tracking and routing carriers along conveyor lines
Environmental Protection Agency	• Tracking radioactive materials
Food and Drug Administration	• Tracking pharmaceutical drugs for product integrity/anti-counterfeiting
General Services Administration	• Distribution process • Identification of contents of shipments • Tracking assets • Tracking of evidence and artifacts
National Aeronautics and Space Administration	• Hazardous material management
Social Security Administration	• Warehouse management

Source: *United States Government Accountability Office (GAO) (2005). Report to Congressional Requesters*—INFORMATION SECURITY: Radio Frequency Identification Technology in the Federal Government *(May 2005).*

The interest in RFID systems for libraries is high. This is because in library operations, RFID can:

- Enable self-checkout.
- Reduce the time librarians spend handling materials (by as much as 75 percent in Frisco, Texas).
- Enable library staff to more easily locate lost/misplaced items.
- Reduce repetitive stress injuries.
- Empower librarians to engage in more "value-add" services with library patrons (such as research assistance and storytelling).

Dr. Ron Heezen, director of the Frisco Public Library, commented: "We wanted to redesign our library for the next generation, as it became very clear to me that all public libraries will have to make do with fewer employees and tighter budgets in the future" (quoted in Anonymous, "Frisco Public Library Deploys RFID Technology," 2005, n.p.).

Yet, there is a civil-liberties aspect to implementing the technology in public libraries. In fact, privacy concerns led the San Francisco Board of Supervisors to deny funding in July 2005 for an RFID system that would have replaced bar-code-based tracking at 12 of the 28 branches of the San Francisco Public Library. Similar concerns were also brought to the fore across the bay when the Berkeley Public Library actually installed an RFID pilot system in 2004 (O'Connor, "SF Library Denied Funds for RFID," 2005).

Document/Evidence Tracking

One of the most promising applications of RFID technology is in the area of file tracking. While many government agencies are attempting to move to a paperless environment, the fact remains that, for most, the manila folder is at the heart of their operations. However, building upon systems designed for law firms to better organize and track their files by employing RFID tagging, legal agencies are taking the lead in the public sector to better manage their paper files.

In DeKalb County, Georgia, the juvenile court works with more than 9,000 children annually, requiring the court system to track over 12,000 manila file folders. DeKalb County estimates that, on average, clerks spend about 10 hours each week simply searching for lost files. According to Juvenile Court Judge Robin Nash: "We have about 2,200 cases of neglect investigated every year, and between 1,100 and 1,200 kids in foster care at any given time. My assistant spends about two hours daily trying to track down files on the three floors of the courthouse, and we believe the RFID system will become a huge labor savings" (cited in L. Sullivan, "Georgia Court System Hopes to Trial RFID," 2005). Thus, DeKalb County is spending $50,000 to tag file folders with RFID labels and equip clerks with desk-mounted and handheld readers. DeKalb County is projecting that the payback on this system will come within two years, as it estimates that the reduction in lost files will save the juvenile court approximately $30,000 each year. When a new, larger courthouse opens in 2007, the county plans to outfit the building with an RFID file-tracking system throughout the facility (L. Sullivan, "Georgia Court System Hopes to Trial RFID," 2005).

Across the country, similar results have been achieved in installations of RFID file-tracking systems in Marin County, California, and Maricopa County (Phoenix), Arizona. In Marin County, for example, 13.56 MHz tags embedded in file labels enable employees to track files. The main benefit of the file-tracking system, in the view of Marin County District Attorney Ed Berberian, Jr., is that it dramatically cuts down on the wasted time in locating misplaced and lost files, a cost his office estimates to be approximately 2,500 manhours per year. If employees should not be able to locate a file in their office, the 3M system allows them to use handheld devices to track down the wayward file. Likewise, in Marin County, staff members routinely screen each of the 40 attorneys' offices several times a week to catalog the files in their possession. The systems employed in both jurisdictions enable employees to be alerted if a file is physically misfiled or placed out of order in a storage drawer or file cabinet. They also use reading pads that can successfully scan a stack of files a foot high (Swedberg, "Marin County DA Saves with RFID," 2005).

Hazardous Waste

RFID has proven to have significant potential in improving the handling of the most critical things—like hazardous waste. For example, the Department of Energy (DOE) is currently overseeing the cleanup of the Hanford nuclear site, the former plutonium production facility in Washington State. With its private contractor, Bechtel Hanford, the DOE is transporting 4,000 tons of radioactive waste daily from around the 586-square-mile, 200-mile-long Columbia River Corridor area to a central landfill facility. Prior to the May 2005 introduction of the RFID-based system, when the trucks bearing the hazardous waste were weighed prior to entering the landfill, operators had to manually key in the identity codes for both the truck and each of the up to 10 steel cans bearing tons of waste for over 200 truckloads daily. The system uses active tags operating at 315 MHz, with a range of 100 feet. Steve Teller, who directed the RFID deployment for Bechtel Automation Technology, reports that the system is presently achieving a 98 percent read rate, in spite of the challenge of dealing with the metal cans. Teller stated: "We use cans with four different

The Use of RFID in the Intelligent Trade Lane Solution

By Bryan Barton

Another example of the use of RFID is reflected in the recent announcement by IBM and Maersk Logistics to develop and test an Intelligent Trade Lane Solution. The goal of this initiative is to develop an end-to-end approach to moving goods from the manufacturer to the store shelf with a higher degree of quality, security, efficiency, and visibility along the entire supply chain. An Intelligent Trade Lane will transform the transportation and logistics industry and improve cross-border security, because it eliminates the information gaps that currently weaken supply chains. RFID will play a major role in enabling this approach.

Intelligent Trade Lane incorporates tamper-resistant embedded controller (TREC) devices, which are attached to containers at the step-off point—typically a manufacturer's loading dock. TREC devices are highly intelligent. They can be programmed, and connected to hundreds of sensors within the shipping container, which enables them to monitor their position as well as the environment and contents inside of the containers while in transit. The devices can transmit and report on data they receive. Moreover, they can store pallet-level manifest information gathered by handheld scanners that read bar codes or RFID tags embedded in the manufacturer's packaging. Examples of other sensors include temperature, humidity, radiation, light, sound, and other specialized types of sensors.

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designs. If you look at them, you wouldn't think the designs are very different, but those little differences become big differences when you're using RFID, because the radio waves are bouncing off everything" (O'Connor, "RFID Helps Hanford Manage Waste," 2005, n.p.).

At the Dryden Flight Research Center at Edwards Air Force Base in California, a team of NASA innovators has shown how RFID can be combined with sensor technology to enhance the safety of handling hazardous materials. Ralph Anton, NASA Dryden's chemical program manager, commented: "When we heard about RFID, we saw its potential. But instead of just producing a PowerPoint slide show of what RFID could enable, we went ahead and developed a working solution to prove it" (quoted in Collins, "NASA Tries RFID for HAZMAT," 2004, n.p.). Their pilot in late 2004 demonstrated how RFID tags, augmented by temperature sensors, could be used to monitor the proper storage of hazardous chemicals in one of Dryden's five storage facilities. The system developed by the NASA engineers tied in to the existing hazardous materials management system, enabling alerts to be triggered if a tagged chemical bladder, container, or cardboard box holding a chemical was moved, was stored incorrectly, or reached a threatening temperature. The Dryden test showed that safety could be enhanced while producing labor savings in the physical monitoring of the hazardous chemicals. Perhaps even more importantly, the pilot demonstrated that RFID labeling could enable emergency responders to more quickly access information on the chemicals they were dealing with, should an incident occur off-site (Collins, "NASA Tries RFID for HAZMAT," 2004).

The initial NASA test further demonstrated the value proposition for RFID in the handling of even non-hazardous chemicals, and the agency is planning to extend it to cover all chemical storage at the Dryden facility. According to NASA's Anton: "Storing at the correct temperature can extend the useful life of chemicals. Given that for every $1 spent buying a chemical it costs about $10 to dispose of it, monitoring the temperature can save the government money in the future" (cited in Collins, "NASA Tries RFID for HAZMAT," 2004, n.p.).

'Critical People' Tracking

RFID can also be used to track the most critical possible thing—namely, people. In Mexico, Attorney General Rafael Macedo de la Concha made headlines last year when it was announced that he and 160 federal prosecutors and drug investigators were implanted with subcutaneous RFID chips to provide the most secure access possible to Mexico's new federal anti-crime information center. The number of chipped officials in Mexico reportedly grew to include key members of the Mexican military, the federal police, and even staffers in the office of Mexico's president, Vicente Fox (Anonymous, "Mexico Tagging Federal Crime Fighters with RFID Chips," 2004).

While nothing like this would be a widespread practice for government in the United States, due to the obvious civil-liberty concerns, there are several exemplary public sector examples of the use of external RFID tags for what might be categorized as "critical people." First, borrowing from the RFID-enabled smart bands that have been successfully used at theme parks (Dignan, 2004), patients can be tracked using RFID-equipped smart brands or bracelets. For instance, the U.S. Navy used smart bands to identify the wounded aboard hospital ships in the Iraq War in 2003, replacing the "Civil War technology" of tracking patients through the use of paper-based charts (Ewalt, 2003). The Los Angeles County Sheriff's Department has earmarked $1.5 million for a program to monitor inmates using active RFID bracelets, which will commence in January 2006. The sheriff's office feels that the technology is a good investment, since it will aid in enhancing security and in decreasing violent incidents (L. Sullivan, "Where's RFID Going Next?" 2005). Finally, after pilot testing an RFID-enabled access card program at the Marshall Space Flight Center in Alabama, the National Aeronautics and Space Administration (NASA) plans to implement a system to deploy 100,000 "smart cards" by 2006. With RFID-enabled access cards, NASA hopes to achieve improved security and access control (Bacheldor, 2004).

Summary

In sum, the government at all levels should be a test bed for RFID technologies. Much of the message today is that it is important to begin to experiment with, to pilot, and to plan for implementation of RFID, even if the business case for doing so can be categorized as being "fuzzy." In the view of the president of EPCglobalUS, Mike Meranda: "You learn by doing, even though the technology is not perfect" (quoted in Albright, "RFID Worth the Risk," 2005, n.p.). Speaking in April 2005, former U.S. Department of Homeland Security Secretary Tom Ridge commented: "The return on investment most businesses want is a little bit different than the return on investment you might find in the public sector.... This [RFID] will improve efficiency. This will improve accountability. This will improve the bottom line. And, oh, by the way, as a direct consequence, this will also enhance security" (quoted in Wasserman, 2005, n.p.). Thus, government can and should undertake RFID projects that may produce ROI over a longer period than could be done by their private sector counterparts, and work to "push the envelope" and expand the knowledge base on RFID technology in the process.

RFID should be viewed as part of a larger wave of wireless technologies that are fast becoming a significant part of the governmental IT market. Writing in *Washington Technology,* Welsh (2005) observed that "RFID is quickly moving from being viewed as a standalone technology to one that can be blended with complementary technologies into more robust solutions" (n.p.). However, he also cautioned that it will be difficult for governments to pursue these solutions when they are struggling with their own budgets. Thus, it is very likely that the federal government will have a role to play in encouraging governmental applications of RFID technology at the state and local levels. This could be done through grant programs and demonstration projects from various agencies. However, as we have seen the potential for government to aid in programs that foster both technological and economic growth (such as President Bush's hydrogen car initiative), the stage would seem to be set for a wider RFID initiative at the federal level. Such a presidential initiative would certainly place RFID on the national agenda, spotlight its potential to find new ways to do things better, and create companies, jobs, and technological progress in the process.

Standards for RFID Technology

One of the factors propelling RFID technology to prominence today is the fact that the RFID industry—through the extraordinary collaboration of vendors, retailers, manufacturers, governments, and academic institutions—is forging a set of standards for RFID technology. Like the railroads and the Internet, for RFID to "work" and to allow for data exchange and collaboration between supply chain partners, it was essential that there be a "common set of standards" for RFID operations. In fact, as Burt Brooks, the director of the U.S. Navy's Automatic Identification Technology Section, put it plainly: "Without a standard in place, any project is a flash in the pan" (quoted in Aitoro, 2005, n.p).

EPCglobal and the International Standards Organization (ISO) are currently the two standards bodies for RFID technology. The standards for RFID technology generally encompass four areas:

- **Air interface protocol:** how tags and readers communicate
- **Data content:** how data on the tags are organized

- **Conformance:** how RFID products are to be tested to meet the standard
- **Applications:** how RFID applications are to be used

EPCglobal, Inc. is a nonprofit joint venture between EAN International, creator of the European Article Number, and the Uniform Code Council (UCC), creator of the Universal Product Code. EPCglobal is a subsidiary of GS1, a global nonprofit organization that develops, creates, and manages EAN-UCC standards jointly. It is the successor to the Auto-ID Center at MIT, which originated the Electronic Product Code concept and laid much of the scientific research and administrative foundation for the commercial and governmental use of RFID technology. In the spring of 2005, EPCglobal announced that its UHF Generation 2 (Gen2) air interface protocol standard had been ratified by its members. Gen2 tags have been shown to be readable at up to 1,500 tags per second, which is approximately five times faster than current applications. EPCglobal is presently working with the European-based ISO to harmonize global RFID standards (Savvas, 2005). However, it is very likely that even the much-celebrated Gen2 standard will not be "it" for RFID's development.

Like the experience with prior revolutions—the railroads, computing, and the Internet—there is a need for a common set of standards so that RFID tags can be formatted, can communicate, and can be interoperable and universal. As Malone (2005) remarked, "The idea of more than one RFID standard being used globally is not just disturbing, it could be disastrous" (n.p.). One need look no farther than your desktop to find the perfect example of multiple standards, as the lack of compatibility between Windows- and Apple-based computers has hindered communications between users of the two systems. As Sirico (2004) commented, the EPC is likely to be the "golden spike" of the RFID revolution, enabling linkages between organizations, since "unless tag data can be transmitted among manufacturers, distributors, and retailers, we have nothing but a promising mess" (n.p.).

In July 2005, EPCglobal amended its tag data standard to enable DoD suppliers to use the legacy Department of Defense Activity Address Code (DODAAC) or the Commercial and Government Entity (CAGE) codes to comply with the Defense Department's January 2007 RFID mandate. Now, readers equipped with software to interpret the EPC data structure will also be able to read DODAAC or CAGE codes without the need for additional software. This revision of the EPC standards is an important step in having a common standard that will be readable throughout the commercial and military supply chains. To this end, the Defense Department's Estevez commented: "I did not want to have a one-off data construct for the DoD—I wanted to have a standard data construct" (quoted in O'Connor, "Tag Data Standard Supports DOD Codes," 2005, n.p.). In a similar vein, EPCglobal is working with a number of vertical markets to incor-

Gen2—and Gen3, Gen4, Gen5 …

According to Sesh Murthy, director of IBM's RFID and Sensors Unit, by 2015 all supply chain processes will use RFID. And, a decade from now, the very nature of RFID will change, as Murthy believes that we will evolve to have "Super RFID," integrating today's microchip technology with sensors that can alert systems for condition changes critical to that item (op. cited in Best, 2005). Sensors could be geared to a wide variety of conditions, including:

- Altitude
- Chemical properties
- Electrical properties
- Flow
- Imaging
- Level
- Motion
- Positioning
- Pressure
- Proximity
- Shock and vibration
- Speed
- Temperature (Malone, "Sensing the Future," 2004).

Ricadela (2005) predicts that the market for "multi-sensor fusion" will be strong, considering that high-value products and even hazardous materials are especially suited for such sophisticated types of monitoring.

porate their legacy codes into the tag data standard. For example, in the automotive industry, work is progressing to incorporate Vehicle Identification Numbers into the tag data standard (O'Connor, "Tag Data Standard Supports DOD Codes," 2005).

Research on RFID Technology

Moving forward, there will be a great need to conduct academic research on RFID technology. This will generally fall into three categories:

- "Nuts and bolts" research
- "Big picture" research
- "Ramifications and permutations" research

Of course, all of these areas are interdependent, and none can or should be conducted in isolation of the others. One of the hallmarks of the development of RFID to date has been the openness of companies, executives, and academics to share their research, lessons learned, and best practice findings. Hopefully, this will continue to be a hallmark of this area of technology.

'Nuts and Bolts' Research

The first area of research, which can be best described as "nuts and bolts" research, will perhaps be the most active in the short term. For the next five to 10 years—and perhaps longer—there will be a great need for basic research into just how to make RFID technology work in various settings. This will involve such fundamental questions as:

- How and where should tags be applied to pallets, cases, and individual items to maximize their readability?
- How should individual readers be positioned to maximize their ability to scan tags, and how should arrays of readers be stationed to best ensure coverage of a specific type of area?
- What can be done to mitigate the effects of metals, water, and other environmental conditions on the ability to read tags?
- What are the environmental consequences of RFID tags, and what measures will need to be taken in the future to mitigate the pollution and landfill problems that might be created through widespread use?

Certainly, much of this research is being conducted by individual organizations, and the hope is that companies and governmental agencies will continue to be as open in sharing their best practices and lessons learned with the wider RFID community through presentations and written reports/case studies as they have been in the formative stages of the RFID revolution. If such research begins to be held as proprietary information, then the rising tide for RFID will be held back.

Academic work is also greatly needed in this area of RFID research. However, at this early point, even if corporate and governmental interests wanted university involvement, there are very few true RFID experts in academia, and few schools that have placed emphasis to date on such research. Right now, perhaps the leading center for such research is housed at the University of Arkansas. Funded by three Arkansas-based companies (Wal-Mart, J. B. Hunt, and Tyson Foods), as well as leading RFID vendors, the Fayetteville campus's RFID Research Center, which opened in June 2005, has at its heart a 7,800-square-foot "dirty lab." The lab gives University of Arkansas researchers the ability to test tags and readers in real-world simulative conditions analogous to warehouses, loading docks, and store shelves (Roberti, "University Opens RFID Research Center," 2005). Certainly, other entrepreneurial-minded universities with similar capabilities in their business, engineering, and even public administration programs will follow suit in the near future.

With the federal government's use of RFID, agencies such as the National Academy of Sciences, DoD, and the USDA should look to provide funding opportunities for centers for academic research into RFID. The centers could be focused, like the University of Arkansas' RFID Research Center, or more encompassing of all three areas of necessary research.

'Big Picture' Research

The second category of research will address the impact RFID can and will have on the "big picture" of organizations, both in the private and public sectors. This will focus on how RFID has and will affect organizations, both in terms of their internal systems/operations/capabilities and with their interorganizational relationships. In the latter regard, research should focus not only on supply chain relationships, but how real-time data sharing impacts areas such as service delivery, finance and payments, and customer service. This research should be carried out by discipline specialists in the areas of:

- Strategic management
- Marketing
- Healthcare administration
- Supply chain management
- Public administration
- Engineering
- Communications

Again, there is great need for cross-disciplinary research and communication, as concepts, theories, models, and cases from one area may apply equally well, if not better, in different application areas.

'Ramifications and Permutations' Research

The final area of research should be in what can be categorized as "ramifications and permutations" research, examining RFID's impact on society, business, law, privacy, and ethics. Less applied than either of the prior two areas, this may be the toughest category of research to find funding and support for. However, it may well be the most important area of research. This area should draw upon the wealth of many disciplines, including, but by no means limited to:

- Law
- Ethics
- Psychology
- Sociology
- Anthropology
- Computer science
- Information management
- Strategic management
- Healthcare administration

This area would encompass research into how RFID technology is challenging and changing the boundaries, norms, and laws in specific areas of business, government, and society. It may at times be controversial and bring to light varying perspectives on the impact of this new technology on people's lives.

Education on RFID Technology

As the advance of RFID technology continues, there will be a great need for RFID-specific educational efforts to be undertaken. These will need to be carried out on several distinct but often interrelated levels, with different audiences with different needs, goals, and objectives for RFID-related educational content. These include, but are no means limited to, the following audiences:

- Managers/executives
- Technical staff
- The general public

Training for RFID Skills

On a technical level, we are presently seeing a shortage of "RFID talent" (Roberti, "Real RFID Talent Will Cost You," 2005). This comes as a consequence of the rapid rise of the technology, which has not seen a corresponding increase in the ability of universities, corporate training staffs, and industry associations to produce skilled professionals who are truly knowledgeable in RFID technology.

According to a 2005 executive survey conducted by the Computing Technology Industry Association (CompTIA) and reported at the RFID World 2005 Conference:

- 80 percent of respondents felt there were insufficient numbers of skilled RFID professionals to meet the demands of the marketplace
- Two-thirds of respondents believed that sufficiently training and educating their employees in RFID technology will be one of the most critical challenges they will face in succeeding with RFID (Fletcher, 2005).

There are a slew of RFID training programs and seminars on the market today, and there will be great demand for such training services in the corporate and government markets for some time to come. As such, there will be no shortage of firms seeking to tap into this market. However, many of them are geared toward advocating a specific firm's solution, resulting in more of a sales focus than an "education for education's sake" approach. One of the most promising developments is the push to craft RFID certification programs. The most prominent of these is being led by the CompTIA trade association (Barlas, 2005).

RFID-Necessitated Retraining

A final aspect of education is the fact that as fuller-scale implementation of RFID takes place in supply chain applications, there will most certainly be lost jobs, particularly in jobs where employees "count things" (Committee on Radio Frequency Identification Technologies, National Research Council, 2004). The number of people employed in inventory-related jobs, in both distribution centers and retail locations, will likely decline in direct proportion to the automation of counting and verification tasks. While employees will always be needed to drive the forklifts and arrange articles so that they can be read, as tag readability closes in on 100 percent accuracy, the number of "monitoring" employees will be lessened. Thus, impacted employees will need training in new skills for positions in the supply chain for higher value-added activities and in entirely new settings.

Likewise, as the ramp-up of RFID will impact "hands-on" distribution jobs, it will likely have an even greater impact on managerial jobs in supply management operations. As full-scale implementation of RFID comes to pass and as visibility is gained across supply partners, more and more exceptions will be handled automatically through software and decision agents, rather than by an actual human decision maker. Thus, managers whose roles have formerly concentrated on taking actions in routine supply chain functions (i.e., estimating, reordering, and shifting stock) will likewise find themselves in need of training and education to engage in higher value-added activities.

Privacy-Related RFID Issues

Introduction: RFID and Privacy Issues— No April Fool's Joke

In Phoenix, Arizona, the Maricopa County Public Library system announced that it was undertaking an RFID pilot program to implant library patrons with a chip in their foreheads that would serve as their library card. It turned out that this "news" was a hoax from the staff at the *Library Journal* for April Fool's Day 2005 (Anonymous, "RFID Implants: The New Library Card," 2005).

As Paul O'Shea (2003) reminds us, RFID is a technological tool, and "as with all technology, it can be used to manipulate our world or be abused for unwarranted control" (n.p.). The fears of "Big Brother" use of the technology are widespread. It is only inflamed by references to the Biblical "Mark of the Beast" (J. Jones, 2005) and to Orwellian popular culture as depicted in such movies as *A Beautiful Mind* and *Minority Report*. Katherine Albrecht, head of Consumers Against Supermarket Privacy Invasion and Numbering (CASPIAN), is widely regarded as the leading critic of RFID technology at the consumer level. She has warned of the nefarious use of RFID by government and led boycotts against Benetton, Gillette, and Wal-Mart for their trials of RFID without consumer knowledge. She once posed the rhetorical question: "What would a Saddam Hussein do with RFID?" (cited in Manjoo, 2003, n.p.).

RFID: Fact vs. Fiction?

Fact is sometimes blurring with fiction when it comes to RFID. Consider the following items from just this year. The Brittan Elementary School Board in Sutter, California, allowed a local firm to outfit its students with RFID-equipped ID badges. The move drew a firestorm of criticism from parents and interest groups, including the American Civil Liberties Union, the Electronic Frontier Foundation, and the Electronic Privacy Information Center. The parents of a 13-year-old student at Brittan Elementary School, Jeffrey and Michele Tatro, commented that "our children are not pieces of inventory" (cited in Swank, 2005, n.p.) The district quickly ended the program (Zetter, 2005).

Researchers from the University of Durham conducted a study for Britain's general trade union, the GMB. They found that early adopting firms of RFID technology, including Tesco, could use the readers put in place so far to track not only products but workers. In fact, the Durham study found that in the UK alone, as many as 10,000 warehouse and logistics workers were being surreptitiously monitored. GMB union leaders called for an end to what they termed "prison surveillance" methods and the enactment of protective legislation in Parliament (Anonymous, "RFID Tags Need Privacy Policies," 2005).

Perhaps the ultimate nightmare for those who fear the privacy aspects of RFID tagging is the prospect of tagging human beings. As discussed in the animal-ID case study, such subdermal tagging has been carried out with animals for years. That same technology can now be easily used in the human body as well. However, it is far more controversial in homo sapiens than in cats and cows.

In fact, the practice has garnered headlines this year, as there has been a rash of high-profile individuals who have announced they have been implanted with RFID tags to allow medical personnel access to their medical records. These include Tommy Thompson, President George W. Bush's first secretary of health and human services and a former governor of Wisconsin, who announced in July that he was being tagged after joining the board of Applied Digital, the company that produces the VeriChip for human and animal implantation (Kanellos, 2005). Likewise, John Halamka, M.D., the CIO of both the Harvard Medical School and Boston's CareGroup Healthcare System, became the first volunteer for Applied Digital's testing of the VeriChip as a medical auto-ID, after the company received FDA approval for its use as a Class II medical device in December 2004 (Anonymous, "Health CIO is RFID-Enabled," 2005). An emergency-room physician himself, Dr. Halamka, who likes to mountain climb in his spare time, explains that he signed on to have the chip implanted so that if he were to be unconscious after a mountain-climbing accident, treating physicians in the emergency room could simply scan the chip in his arm to obtain a 16-digit access code to access his health records (Evans, 2005).

Although there will inevitably be an evolving and important debate over the efficacy and ethics of using RFID for medical reasons, subdermal tagging can also be used for completely "convenience" reasons. For instance, the Bar Soba nightclub in Scotland recently became the first known user of such tagging for bar patrons who choose to have a device implanted in their arm (customers who elect to do so can have the VeriChip implanted anywhere on their body by a medical professional who performs the procedure in the nightclub). While critics assail this use for both privacy concerns and fears that it could encourage excess drinking, the club's owner, Brad Stevens, points out that the chip will allow his establishment to provide top-flight service to its patrons. Stevens gave the example that for a tagged customer, there would be no need to carry cash or credit cards, and "by the time you walk through the door to the bar, your favorite drink is waiting for you and the bar staff can greet you by name" (quoted in Anonymous, "RFID Enables Wallet-less Drinkers," 2005, n.p.).

Privacy Legislation and RFID

Fears surrounding the privacy aspects of RFID have led to the introduction of proposed legislation, both at the state and federal levels, to regulate or prohibit the use of RFID at the consumer level. Actions to date in this area are summarized in "Proposed RFID Legislation."

An RFID "Bill of Rights" has even been proposed in the journal *Technology Review*. It includes:

- The right to have RFID tags removed or deactivated when they [consumers] purchase products.
- The right to use RFID-enabled services without RFID tags.
- The right to access an RFID tag's stored data.
- The right to know when, where, and why the tags are being read (Garfinkel, 2002, p. 35).

The Federal Government and RFID Privacy

On March 10, 2005, the Federal Trade Commission (FTC) (2005) released a report titled *RFID: Applications and Implications for Consumers*. The report was an outgrowth of a June 2004 workshop conducted by the FTC, which involved representatives from all sides of the RFID debate.

RFID users, including:

- Marks & Spencer
- Procter & Gamble
- Wal-Mart

RFID trade organizations, including:

- EPCglobal

Proposed RFID Legislation

Several attempts have been made, both at the federal and state levels, to pre-emptively protect consumer privacy in the coming age of RFID. These include the following pieces of legislation that have been introduced thus far:

- **Federal—**H.R. 4673 would prohibit the retail sale of any product containing an RFID tag unless the product contains a warning label and the customer is given the option of removing the tag at the point of sale.
- **California—**S.B. 1834 would permit retailers or libraries to collect information via RFID only in regard to items customers actually purchase, rent, or borrow; information cannot be collected on items customers pick up but put back, or what they are wearing or carrying on their person.
- **Maryland—**H.B. 32 would establish a task force to study privacy issues related to RFID uses by retailers and manufacturers to determine whether those uses should be restricted or prohibited.
- **Missouri—**S.B. 867 would require that any product containing an RFID tag have a label disclosing that information to the consumer.
- **Nevada—**B.D.R. 487 would require notification to consumers if an RFID tag is embedded in a product.
- **Utah—**S.J.R. 10 would implement a study of business practices related to RFID, including the feasibility of disabling tags at the point of sale.
- **Virginia—**H.B. 1304 would require public bodies to conduct a privacy impact analysis when authorizing or prohibiting "invasive technologies," including RFID (Quirk and Borrello, 2005).

By far the most serious effort at RFID-restricting legislation has come in California. In the spring of 2005, State Senator Joe Simitian (D-Palo Alto) introduced Senate Bill (S.B.) 682, known as the Identity Information Protection Act. On May 16, 2005, S.B. 682 was approved by the California State Senate by a vote of 29 to 7. As of the writing of this report, the bill is in conference and being amended in the State Assembly; its ultimate fate remains to be seen. However, the bill is the most RFID-restrictive legislative proposal offered to date. Senator Simitian's bill would severely limit the use of RFID in state-issued identification devices, including specifically:

- Driver's licenses
- Student and government employee ID cards
- State-issued health and benefit cards
- Public library cards (O'Connor, "Calif. Bill Seeks to Ban Tags in IDs, 2005).

For an RFID tag to be used for these purposes, the bill would require that encryption be used and that the ID holder be informed of the presence of the RFID component of the ID card, as well as where and when the ID might be interrogated. As presently constituted, the bill specifically exempts IDs used in corrections and state-run medical facilities and office buildings, as well as IDs for emergency first responders and automatic toll-bridge-collection transponders (O'Connor, 2005, "Calif. Bill Allows RFID in More IDs," n.p.). The bill would also outlaw the practice know as "skimming," explained by the American Library Association (2005) as "the surreptitious use of an electronic reading device to collect RFID data from an unsuspecting person carrying an object with an embedded chip" (n.p.).

The bill, which has received public support, has also drawn criticism from both the California Chamber of Commerce and the High-Tech Trust Coalition, a coalition of leaders in the automatic identification industry. While Senator Simitian has compromised from his initial stance, calling for an outright ban on the use of RFID in state IDs, he contends: "The [RFID] industry would be well advised to take a long view of this," advising the RFID industry to "recognize the legitimate concerns that the public has about this technology" (opinion cited in O'Connor, 2005, "Calif. Bill Allows RFID in More IDs," n.p.). This is a sentiment echoed by many in regards to RFID. In fact, El-Amin (2005) recently commented: "The technology's limits are not the point. RFID may have limited capacity and deal with mundane data, but it is also a technology of which the public is deeply suspicious" (n.p.).

Whatever the ultimate fate of Senator Simitian's bill, California, due to its sheer size, will likely play a major role in determining the future use of RFID in public ID cards and documents. The controversy over S.B. 682 is likely the first shot in a serious debate over how, when, and where RFID can be used by governments for identification purposes.

- The Grocery Manufacturers of America
- The National Retail Federation

RFID developers and consultants:

- Accenture
- CapGemini
- Intel
- Microsoft
- Philips Semiconductors
- Sun Microsystems
- Texas Instruments

Consumer advocacy groups, including:

- CASPIAN (Consumers Against Supermarket Privacy Invasion and Numbering)
- The Electronic Frontier Foundation
- The Electronic Privacy Information Center.

The June 2004 workshop examined the following items: (1) an overview of RFID's key components and how the technology works; (2) the range of current and anticipated applications for RFID, especially where consumers may encounter it; (3) the implications for consumers, including privacy and security issues, of these different uses; and (4) existing and proposed approaches to addressing these issues.

Despite calls from privacy advocates to issue RFID regulations, the FTC decided to urge the users and developers of RFID to self-regulate usage of the technology, while promising that the agency would continue to monitor developments in this area. The FTC's report places responsibility on those organizations—both private and public—that make and use RFID technology to be "the 'go-to' guys" for educating consumers about RFID use, data collection, and privacy concerns (Anonymous, 2005, "Federal Trade Commission Takes 'Hands Off' Approach to RFID," n.p.). As such, the FTC urged both retailers and RFID technology providers/integrators to have industry-led initiatives on these matters and to actively share best practices in these areas. Moreover, the FTC recognized that the consumer privacy issues associated with RFID are inextricably tied to the larger issues of database security. Therefore, companies using RFID data must conform to existing federal guidelines regarding the corporate safeguarding of personal data (Collins, "FTC Asks RFID Users to Self-Regulate," 2005).

From a procedural perspective, privacy must be a consideration in all federal RFID initiatives. The E-Government Act of 2002 requires agencies to produce a privacy impact assessment (PIA) when they decide to undertake an information technology project or redesign a business process that incorporates new technologies. These PIAs must be published and made available to the public. Thus, in the view of Kenneth Mortensen, an attorney with the U.S. Department of Homeland Security's (DHS) Privacy Office who spoke on the subject at a privacy forum in July 2005, "We have privacy baked in" on all federal RFID projects. He cited as an example the DHS US-VISIT (United States Visitor and Immigrant Status Indicator Technology) program, which will incorporate RFID and biometric technology at border crossings with Canada and Mexico. His office filed the PIA for the project in January 2004 and continues to work with project managers and technologists, asking questions like: "What is the purpose?" and "Why am I using or collecting or storing this information?"—questions intended to help project teams incorporate privacy considerations into their proposed designs and solutions (quoted in Wasserman, "Agencies Affirm Privacy Policies for RFID," 2005, n.p.).

Summary: Privacy—An Ongoing Concern

Certainly, privacy will continue to be a huge issue in the development of RFID, especially as the technology begins to migrate to the consumer level. We have seen this again and again, from the time shoppers began encountering RFID tags at Wal-Mart's Sam's Wholesale Clubs in Texas (L. Sullivan, "Wal-Mart Takes RFID to Sam's Club," 2004) to the recent controversy over the U.S. State Department's attempts to place RFID chips in U.S. passports (Biba, 2005; Lipowicz, 2005). It will behoove those in both the public and private sectors to maintain a "finger on the pulse" of the public and of workers to gauge their understanding of and misapprehensions about the capabilities of RFID technology. There is a significant risk, as with the actions in California, to have policy go beyond protecting individual rights and hamper the full use and deployment of the technology. This could perhaps delay or make impossible breakthroughs that could aid the public in retail, healthcare, and many other areas of their lives. Further, with significant concern over identity theft and other forms of hacking, as cases of such are reported with RFID (Hesseldahl, 2004), calls for encryption and other forms of protection for RFID tags may be furthered.

Conclusion: 'Uncle Sam's Guiding Hand'

For at least a decade to come, we are likely to see the U.S. government's investment in automatic identification technologies and its formal and informal mandates create profound changes in the way *all of us* conduct business and even live our lives. If so, it would be history repeating itself. When we look at federal programs, the direct ROI for the spending is often minuscule when compared to the spin-off effects of the technological developments. This has occurred several times over the past few decades, including:

- The 1960s and 1970s with NASA and the space program
- The 1980s and 1990s with the Defense Department and ARPANET, which laid the foundation for the Internet
- The current post–September 11 environment, where the push for greater homeland security is leading to large investments in wireless technologies, scanning, imaging, and data mining, which are already producing technology transfer to private enterprise and public benefit.

A couple of years ago, noted futurist Paul Saffo (2002), director of the Institute for the Future, characterized RFID as this decade's entry into the pantheon of new technologies that have come along to reshape the information technology landscape.

As Dan Mullen, president of AIM Global, put it: "The government was a huge driver in the development of the bar code market, and there is an incredible amount of parallel in how the RFID market is developing." As such, the government "can serve as a model for others who want to explore new opportunities to improve" (quoted in Burnell, 2004, p. 16). Likewise, the Defense Department's commitment to be an early adopter of RFID technologies throughout its complex, worldwide, multi-layered supply chain is likely to advance not just the pace of automatic identification technology development, but the scope, standardization, and utility of RFID technologies in general. In the end, we may well judge the U.S. government's push for RFID technology—through both the military's mandate and the host of other mandates and initiatives across federal agencies—as perhaps *the* key driver to make automatic identification a reality throughout consumer-facing industries in the very near future.

Writing on the subject of "Uncle Sam's Guiding Hand," Greenemeier (2004) argues that the government's role in technology adoption can be a complex one, which both fosters and retards innovation. He shows that throughout history, government—by issuing mandates, by acting as a major purchaser, and by helping to set standards—can be a positive force in advancing technology. However, if regulations and mandates are too constrictive, government can stifle innovation and actually slow the progress and acceptance of the technology. Dave Wennergren, the Navy's chief information officer, remarked that the proper role of government when technology is new and in flux is a leadership position, "to help make some order out of chaos." Wennergren points out that "in a networked world, government can use its size in a united way" to advance the technology and set standards (opinion cited in Hasson, 2004, n.p.).

Conclusion: 'You Say You Want a Revolution...'

In the end, the current push for RFID may be a small part of a larger mosaic. Indeed, Paul Saffo foresees that much of the focus on RFID today is on doing old things in new ways, but the truly exciting proposition is the new ideas and new ways of doing things that will come from RFID. Building upon the previously advanced ideas on RFID as making possible "an Internet of things" (Schoenberger, 2002) or a "wireless Internet of artifacts" (Gadh, 2004), Saffo sees RFID as making possible what he terms "the sensor revolution." This is based on viewing RFID as a *media technology,* making it possible for what he categorizes as "'smartifacts' or intelligent artifacts, that are observing the world on our behalf and increasingly manipulating it on our behalf" (quoted in O'Connor, "RFID and the Media Revolution," 2005, n.p.). Saffo thus stresses the importance of thinking outside the box on RFID and looking beyond today's problems to find "unexpected applications," which is where "the greatest potential for RFID lies" (quoted in O'Connor, "RFID and the Media Revolution," 2005, n.p.). Indeed, Saffo urges people to take a 20-year perspective on RFID, believing that we are in the early stages of "a weird new kind of media revolution," in that "RFID will make possible new companies that do things we don't even dream about" (quoted in Van, 2005, B1).

If we indeed take the long view of history, we can see that some of today's biggest industries, most pedestrian technologies, and most indispensable parts of our lives come from sparks of imagination about how to use a technology in unimagined ways. Indeed, we have seen bar coding itself used in applications far beyond the supply chain functions for which it was created (Brown, 1997). Who would have dreamed that GPS systems would today be routinely used by business executives lost in their rental cars in big cities, and by fishermen and hunters on the bayou? Who would have dreamed that people around the globe, from Moscow, Russia, to Moscow, Idaho, and everywhere in between, would have their own cell phone? In the 1950s, when people gathered around a cumbersome black-and-white television to watch "I Love Lucy," who could have dreamed of a 500-channel universe? Could anyone at DARPA have envisioned the multitude of opportunities for companies such as eBay, Amazon, and Google that would be spawned by the Internet? Just like the RFID-enabled golf balls discussed earlier in this report, today we are seeing the first fruits of this "weird" new media revolution that RFID is sparking (see "The Byproducts of the 'Weird' New Media Revolution").

There will undoubtedly be an "RFID revolution." How far and how fast it will move, and at what cost (both in dollars and privacy) and benefit (to our commerce and, indeed, to our own health) remain to be seen. The trajectory and the timeline for this revolution may be uncertain, and the ultimate scale of RFID's impact on business, society, and indeed our everyday lives spans a very wide margin of error (from minor conveniences to total transformation).

Yet, we can benefit today from being cognizant of the long view of history, knowing how the government has played a role in advancing other communications media. Thus, the public sector should have a different ROI equation related to its RFID investments than any private sector entity can—and perhaps even should—have at present. While companies such as Wal-Mart can look at their internal investments in RFID and hope that others in its supply chain will follow, they must ultimately make their decisions based on what is going on within

The Byproducts of the 'Weird' New Media Revolution

A multitude of RFID applications have been proposed and/or actually piloted in the past year. The following are representative of the kinds of work that are "pushing the envelope" on novel and exciting ways to employ RFID technology to date:

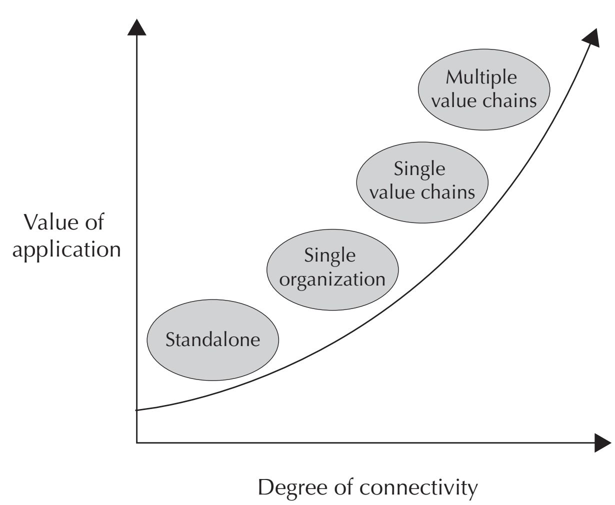
- Outfitting the home environment with networks of RFID-tagged items and readers enables patients with Alzheimer's or other memory impairments to carry out daily tasks and maintain their independence (Want, 2004).
- Art galleries and museums are giving patrons RFID readers to enable them to learn more about the exhibited works they are viewing and enhance their experience, even creating customized CDs and webpages chronicling the individual's unique encounters with the items in a collection (Collins, "RFID for the Art Shy," 2005).
- Theme parks, from Dollywood to Disney, are experimenting with RFID-enabled wrist-band technology in novel ways, from enabling lost children to be located to tracking ride utilization to facilitating patron payments (Dignan, 2004; Margulius, 2004).
- Casinos are employing RFID-enabled chips to extend their visibility to better track table play and to be more accurate in awarding comps to their most valued patrons (Gilbert, 2005; Wyld, "Playing with the House's Money," 2005).
- According to the official Xinhua News Agency, the government of China will affix RFID tags on all of its 163 captive pandas. This step is being taken to better monitor the panda population and to discourage inbreeding. The implantable chip will carry the panda's age, family derivation, and other identifying information (Haines, 2005).

their own four walls. Yet, we ultimately do not—and really cannot—live in a slap-and-ship world. In supply chains, the move has been toward greater integration and cooperation. Likewise, the power of the network has been demonstrated over and over again—through the Internet, mobile telephones, electronic media, and so on. As shown in Figure 14, the larger the net cast by RFID becomes (linking organizations internally and their external supply chain partners, both upstream and downstream), the higher the overall value proposition becomes.

RFID thus presents a classic "chicken and egg" problem, in that wider RFID adoption will likely lower the costs associated with RFID and markedly increase the beneficial aspects. The author of a recent book on RFID, Steven Shepard (2005) categorized the current supply chain as operating under what he aptly described as "the Kevin Costner effect." Adapting the famous line from the movie *Field of Dreams,* he described the layers of players in the supply chain as operating under the philosophy that "if you build it, they will come" (p. 7).

In the long view then, it is likely that an "RFID multiplier" will emerge, whereby one lead entity's RFID spending will cause ripple effects in the form of RFID investments by others in its supply chain, and then on to the next level of derivative supply chain partners down the line. While this concept applies to government RFID investments as well, RFID ROI in the public sector will come not only from the RFID multiplier in the supply chain, but also from the larger spark of those new ideas and new companies that will pursue them in the marketplace. This will lay the ground for job and wealth creation, and make government investments in what Saffo termed a "weird new kind of media revolution" an enticing economic development tool. The public sector's efforts to pilot and implement RFID today and over the next decade will help to advance the RFID knowledge base, establish best practices, overcome some of RFID's technological quirks and physics problems, and set the standards to provide the common set of tracks for the RFID industry.

Figure 14: Increasing Value of Automatic Identification Interconnectivity



Thus, federal, state, and local officials must rightly examine each prospective use of RFID—from the battlefield to the warehouse to the library to the hospital—for the implementation and ongoing costs versus the tangible service gains and cost savings that can be achieved to determine the short-term ROI of their project. They should also know that by making the decision to implement ROI in their venue for their purposes and for the benefit of their stakeholders, they are helping to advance the technology and, ultimately, will help give the technology the lift needed to fly over the long term. Thus, they will help lay the foundation not only for future RFID uses in their own organization but aid the development of the people and companies that will prosper in the midst of the RFID revolution.

Will RFID be "the next big thing"? At this point in the technology's life cycle, it is too early for anyone to tell, but the stars certainly seem to be in alignment for the next decade to be a tremendously exciting one. As the Defense Department's Alan Estevez (2005) recently wrote: "The real value of RFID lies not in what it can do today but in what it will do in the future" (n.p.). As Albright ("Business Intelligence Vendors Sitting Out RFID Rush," 2005) so aptly characterized the RFID challenge, "We're in the very early stages of a marathon" (n.p.). However, Lager (2005) observed that as of August 2005, RFID is "ready for prime time"; the technology has "left the lab" and it is fast entering the mainstream of business (p. 14). Although as Reilly (2005) cautions, while there is a flurry of supply chain and back-office, back-operations activity, we may well not see widespread deployment of RFID in the consumer-facing environment until 2008.

Many share the sentiment of Kuchinskas (2005) that "RFID will change business and society as much as cell phones and the Internet have. While the technology will transform business processes, it also will ease some of life's daily annoyances" (n.p.). One blogger (Grosso, 2004) exquisitely captured the latter sentiment regarding RFID when he wrote: "I'm serious. I don't really care much for Wal-Mart's inventory problems. RFID could solve *my* inventory problems" (emphasis in the original, n.p.). He desired a smart home that could help one locate "unhappy objects," such as a forgotten coffee cup or the TV remote, made intelligent with RFID. For instance, if he couldn't find his bag for a trip, he'd like to have the smart home system prompt him with: "Dude. You left the suitcase in the bathroom under the sink again" (Grosso, 2004, n.p.). If we reach that point, the RFID future will have arrived.

Appendix I: Glossary of RFID Terminology

Active Tag: A type of RFID tag that has its own power supply (battery or external power), and, when interrogated by a reader, emits its own signal. Typically, active tags have far greater read distances than passive tags, and they can be combined with sensors to provide information on the environment and condition of the item. They are also more expensive than passive tags and due to the battery have a limited life span.

Agile Reader: A generic term that refers to an RFID reader that can read tags operating at different frequencies and/or using different methods for communicating between the reader and the tags.

Air Interface Protocol: The rules that govern how RFID readers and tags communicate with one another.

Antenna: Conductive elements designed to radiate and/or receive radio energy. As part of an RFID system, antennas radiate or receive radio energy to/from the RFID tags and the reader.

Anti-collision: A general term encompassing the means of preventing radio waves from one device from interfering with radio waves from another. Anti-collision algorithms enable readers to read more than one tag in the same reader's field.

Auto-ID Center: The private/academic consortium founded in 1999 in conjunction with the Massachusetts Institute of Technology. Through the support and cooperation of major manufacturers, retailers, and the U.S. government, the Auto-ID Center conducted much of the foundational research on commercializing RFID technology and invented the concept of the Electronic Product Code. The Auto-ID Center consortium became EPCglobal in 2003.

Automatic Identification (auto-ID): A broad term encompassing technologies used to help machines identify objects. A host of technologies fall under the Automatic Identification umbrella, including bar codes, biometrics, smart cards, voice recognition, and RFID.

Backscatter: A method of communication between passive RFID tags and readers. RFID tags using backscatter technology reflect back to the reader radio waves from the source, usually at the same carrier frequency. The reflected signal is modulated to transmit data.

Capacity: The number of bits or bytes that can be programmed into a tag. A tag's capacity may represent the bits accessible to the user or the total number, including those reserved to the manufacturer (e.g., for parity or control bits).

Capture Window/Field: The region of the scanner field in which an RFID tag can be read.

Closed System: A system that is under the control of a single owner or authority.

Contactless Smart Card: A card (that can be a credit, buyer, or ID card) that contains an RFID chip to transmit information without having to be swiped through a reader.

Duplex: A channel that is capable of transmitting data in both directions at the same time. A half-duplex channel is capable of transmitting data in both directions, but not simultaneously.

Edgeware: Hardware that runs applications or middleware close to the "edge" of the network, managing and filtering data from readers and other devices. With edgeware, data processing is decentralized, with only screened and/or critical information being passed along to the central database.

Electromagnetic Interference: The interference caused when radio waves of one device distort the waves of another. Cells phones, wireless computers, and even robots in factories can produce radio waves that interfere with RFID tags.

Electronic Article Surveillance (EAS): Acknowledged by many as the first RFID technology widely used in the retail environment and in libraries, these systems use microwave or inductive technology "readers" to detect the presence or absence of EAS tags as a means of detecting and deterring theft. When an item is purchased (or borrowed from a library), the tag is turned off. However, when someone passes a gate area holding an item with an EAS tag that hasn't been turned off, an alarm sounds. These tags are inexpensive and do not contain any data.

Electronic Product Code: A unique number, stored in the chip on an RFID tag, that identifies an item in the supply chain, allowing for tracking of that item.

Electrostatic Coupling: Systems that transfer data or power by inducing electrical voltage on a plate.

EPC: The acronym for Electronic Product Code.

EPCglobal: The nonprofit organization that manages standards and numbering schemes associated with the EPC (Electronic Product Code). It is the successor organization to the AutoID Center. EPCglobal is a subsidiary of the Uniform Code Council and EAN International, the leading retail bar-code-standards organizations. EPCglobal's membership includes leading retailers, manufacturers, and governments from around the world.

European Article Numbering (EAN): The bar code standard used throughout Europe, Asia, and South America, and administered by EAN International.

Excite: A reader is said to "excite" a passive tag when the reader transmits radio frequency (RF) energy to "wake up" the tag, enabling it to transmit back its identification data.

Factory Programming: The process of having an identification number written into the read-only microchip of an RFID tag at the time the chip is made.

Field Programming: Tags that use EEPROM (Electrically Erasable Programmable Read-Only Memory), or non-volatile memory, which can be programmed after being shipped from the factory.

Frequency: The number of repetitions of a complete wave within one second. For example, 1Hz equals one complete waveform in one second; 1KHz equals 1,000 waves in a second. RFID tags use low, high, ultra-high, and microwave frequencies. All frequencies have their own advantages and disadvantages that make them more suitable for some applications than for others.

Frequency Hopping: The protocol used to prevent readers from interfering with one another in their operations by using varying frequencies. In the U.S., even though UHF RFID readers are said to operate at 915 MHz, they actually can operate between 902 and 928 MHz. To avoid conflict with readers operating adjacently, a reader may "frequency hop"—jumping randomly or in a programmed sequence to any frequency between 902 MHz and 928 MHz. If the available band is wide enough, the chances of two readers operating at exactly the same frequency is therefore small. However, as the UHF bands in Europe and Japan are much smaller than those available in the U.S., the frequency hopping technique is not nearly as effective for preventing reader interference.

Harvesting: The method by which passive tags gather energy from an RFID reader's antenna to be able to respond to the reader.

Inductive Coupling: Systems that transfer data or power by inducing electromagnetic current in a coil.

Interrogator: Another name for an RFID reader.

Memory: The amount of data that can be stored on the microchip in an RFID tag.

Misread: The condition that exists when the data presented by the reader for an RFID tag is different from the corresponding identification data on the tag itself.

Nominal Range: The range at which systems can assure reliable operation, considering normal variability of the environment in which it is expected to be used.

Null Spot: An area in the reader field that does not receive radio waves, due to the shape of the waves. It is, in essence, the reader's "blind spot." The null spot is a phenomenon common to UHF RFID systems.

Passive Tag: A type of RFID tag that does not have its own power supply. Instead, the tag draws power from the reader, which sends out electromagnetic waves that induce a current in the tag's antenna. Without an onboard power source, passive tags have a lesser read range than active tags. However, they cost less than active tags and have an unlimited life span.

Phantom Read (also called a "phantom transaction" or a "false read"): The result of an RFID reader inaccurately reporting the presence of an RFID tag that does not exist.

Power Level: The amount of radio frequency (RF) energy radiated from a reader or an active tag. Higher-power outputs enable longer read ranges. However, most governments regulate the power levels at which RFID readers can operate to avoid interference with other RF devices.

Programming a Tag (also called "commissioning a tag"): In the context of RFID, the process of adding identification data to or altering the data in an RFID tag.

Radio Frequency Identification: An automatic identification technology that uses radio waves to identify objects.

Read: The process of retrieving data stored on an RFID tag by sending electromagnetic waves to the tag and converting the radio waves the tag sends back into data.

Read Rate: The number of tags that can be read by an RFID reader in a given time period.

Read/Write: The ability of an RFID system to change the data that is stored in a tag. For example, as a product moves from the final packaging area to the warehouse, a read/write tag can be modified to reflect the new location, so that now, when interrogated, it passes the new location as part of its updated data stream.

Reader (also called an interrogator): A device that communicates with RFID tags. The reader has one or more antennas, which emit radio waves and receive signals back from the tag. Readers may have a digital display to relay information to the operator and may transmit data on to an organization's computer network infrastructure. Readers can be either fixed or portable, and today they are beginning to be integrated into other electronic devices, such as PDAs (personal digital assistants) and cell phones, and even into objects such as pens.

Reader Field: The area of coverage for an RFID reader. If a tag is within the reader field, it can (should) receive the reader's radio wave and be read.

Reader Talks First: The means through which an RFID reader in a passive UHF system communicates with tags in its read field. The reader sends energy to the RFID tags, but the tags sit idle until the reader requests them to respond individually, if more than one tag is present. In a "Reader Talks First" system, the RFID reader is searching for any tags that may be present in the read field. In contrast, in a "Tag Talks First" environment, the tags alert the reader that they are present in the read field.

RFID: The acronym for Radio Frequency Identification.

Semi-passive tag (also called battery-assisted tags): A type of tag similar to an active tag in that there is an onboard battery. The battery is used to run the microchip's circuitry and to boost the effective read range of the tag. Some semi-passive tags sleep until they are woken up by a signal from the reader, which conserves battery life, while some are programmed to broadcast at set intervals of time.

Sensor: A device that responds to a physical stimulus and produces an electronic signal reporting on that stimulus. Sensors can be tailored to report on a variety of environmental conditions, including temperature, movement, vibration, and shock.

Signal Attenuation: The weakening of radio frequency (RF) energy from an RFID tag or reader.

Slap and Ship: The practice by a manufacturer of placing RFID tags on cases and/or pallets at the last possible point before shipping from a supplier to a mandating retailer or other organization. With a slap and ship strategy, a manufacturer or distributor is simply trying to meet the requirements of another firm's RFID mandate, rather than attempting to capture any data—and value—from RFID tagging in its own system.

Smart Label: A generic term referring to a printed label that typically contains printed information, a bar-code identifier, and an RFID tag. The label is considered to be "smart" because of its ability to communicate with an RFID reader.

Tag Talks First: The means through which an RFID reader in a passive UHF system identifies tags in its reader field. When tags enter the field, they immediately communicate their presence by reflecting back a signal. The "Tag Talks First" protocol is useful when you want to know everything that is passing a reader, such as at a dock or warehouse door or when items are moving quickly on a conveyor belt. In a "Tag Talks First" mode, the object is to have after a tag alerts the reader. In contrast, in a "Reader Talks First" mode, the RFID reader is searching for any tags that may be present in the read field.

Time Division Multiple Access (TDMA): A method used to solve the problem of signals from two readers overlapping and colliding. TDMA algorithms enable the readers to attempt to read tags at different times.

Transceiver: A device that can both transmit and receive radio waves.

Uniform Code Council (UCC): The nonprofit organization that oversees the Universal Product Code (UPC), the bar-code standard used in North America.

Universal Product Code (UPC): The bar-code standard used in North America and administered by the Uniform Code Council (UCC).

Write Once Read Many (W.O.R.M) tag: A tag that is designed to be written or programmed once and then read many times throughout its life, without the ability to be updated or modified.

Appendix II: Recommended Further Readings on RFID Technology

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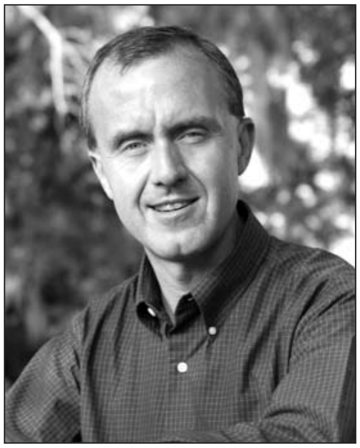

David C. Wyld currently serves as the Maurin Professor of Management at Southeastern Louisiana University in Hammond, Louisiana, where he teaches courses in business strategy and e-commerce. He is the director of the College of Business' Strategic e-Commerce/e-Government Initiative and the founding editor of the *Journal of Strategic e-Commerce*. In the past two years, he has become one of the leading academic experts on the emerging application of RFID technology in both the public and private sectors. He has been a consultant in the field, a prolific writer, and an invited speaker on the subject to both trade and academic audiences, and has commented on the technology on the Discovery Channel and other media outlets. He is currently at work on a book on RFID for Cambridge University Press.

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