NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

RADIO FREQUENCY IDENTIFICATION'S POTENTIAL TO MONITOR SMALL VESSELS

by

John A. Crofts

September 2007

Thesis Advisor:	Nicholas Dew
Second Reader:	Bill Gates

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE**	**3. REPORT TYPE AND DATES COVERED**
	September 2007	Master's Thesis

4. TITLE AND SUBTITLE:

Radio Frequency Identification's Potential to Monitor Small Vessels

5. FUNDING NUMBERS

6. AUTHOR(S) Lieutenant John A. Crofts, NOAA

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Naval Postgraduate School
Monterey, CA 93943-5000

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
N/A

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES The views expressed in this report are those of the author(s) and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited

12b. DISTRIBUTION CODE

13. ABSTRACT *(maximum 200 words)*

This study examines the possibility of applying Radio Frequency Identification (RFID) technology to monitoring small vessels. The study focuses on the technology's applicability to maritime security, resource management, and the public. The costs and benefits of using RFID on waterways are analyzed, with special attention given to privacy and public acceptance. The thesis then discusses a completed proof of concept study and concludes with preliminary guidelines for creating an RFID-driven small vessel monitoring program.

14. SUBJECT TERMS RFID, Radio Frequency Identification, Vessel, Monitoring, Homeland Security, Search and Rescue, Human Use Patterns, Fisheries, Privacy, Panopticon Concept, Affordable Loss

15. NUMBER OF PAGES
79

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	**18. SECURITY CLASSIFICATION OF THIS PAGE**	**19. SECURITY CLASSIFICATION OF ABSTRACT**	**20. LIMITATION OF ABSTRACT**
Unclassified	Unclassified	Unclassified	UU

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release; distribution is unlimited

RADIO FREQUENCY IDENTIFICATION'S POTENTIAL TO MONITOR SMALL VESSELS

John A. Crofts
Lieutenant, National Oceanic and Atmospheric Administration
B.S., St. Olaf College, 1998

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF BUSINESS ADMINISTRATION

from the

NAVAL POSTGRADUATE SCHOOL
September 2007

Author: John A. Crofts

Approved by: Nicholas Dew
Thesis Advisor

Bill Gates
Second Reader

Robert N. Beck
Dean, Graduate School of Business and Public Policy

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

This study examines the possibility of applying Radio Frequency Identification (RFID) technology to monitoring small vessels. The study focuses on the technology's applicability to maritime security, resource management, and the public. The costs and benefits of using RFID on waterways are analyzed, with special attention given to privacy and public acceptance. The thesis then discusses a completed proof of concept study and concludes with preliminary guidelines for creating an RFID-driven small vessel monitoring program.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

LIST OF FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

EXECUTIVE SUMMARY

This thesis considers using radio frequency identification (RFID) technology to monitor the movement patterns of small vessels in U.S. waterways. The intention is to provide a tool to interested decision makers that will inform them of the benefits and challenges of this potential application of RFID technology. This summary introduces a proposed system using RFID to monitor small vessels, briefly discussing a completed proof of concept study. It then identifies the key stakeholders involved and notes the improvements that this system could bring. The summary also considers who might pay for such a system and concludes with a recommendation for further research and action.

To monitor small vessel movement, active RFID tags would be issued to boat owners, who would be responsible for affixing the tags to their vessels. Receivers to interrogate these tags would be placed in narrow waterways that act as bottlenecks (harbor entrances, passes, narrow channels, etc.), as well as in high risk areas. As boats come into contact with a receiver's read field, their tags would be interrogated by an electromagnetic wave, thereby identifying and recording their presence. Video surveillance equipment could be used concurrently to provide complementary visual evidence of vessel activity.

Preliminary field testing was conducted in Santa Cruz Harbor with off-the-shelf RFID equipment and two small vessels. Results indicate that an RFID receiver positioned at 40 feet above sea level could read tags placed in realistic locations on the vessels at a very high read rate. These initial results suggest that implementing an RFID small vessel monitoring system may require minimal technical effort.

The proposed system of monitoring small vessels with RFID offers benefits to several key stakeholders:

Homeland security. Targets of interest could be identified and tracked when within range of RFID receivers. When combined with video surveillance, the system would also allow watchstanders to detect when an untagged vessel passed through an area. Small vessel movement data could be merged with other intelligence data to create actionable information. Further, policies that require small vessels to be equipped with RFID tags might act as a deterrent to small vessel threats.

Search and rescue. An RFID system could reduce the unnecessary deployment of resources for false signals and alarms by providing search and rescue agencies with accurate information about when vessels returned to port. In the case of an actually missing vessel, information about when the vessel left the port could aid search and rescue efforts.

Law enforcement. The persistent surveillance capability of an RFID monitoring system could assist law enforcement agencies in detecting unregistered vessels, tracking vessels engaged in illegal activity, or locating stolen vessels.

Resource management. Resource managers who currently rely on limited observational and survey data could improve their understanding of human use patterns on waterways by using data generated by an RFID monitoring system. Effort data collected by the system would be particularly valuable in managing fish populations.

Private users. Small vessel owners could benefit from search and rescue/law enforcement agencies' enhanced ability to perform their duties. RFID tags could also be used to streamline vessel registration. Because tags are only detected when within range of RFID receivers, the system would also have a relatively limited impact on citizens' privacy (a major concern regarding any system of monitoring human movement).

Because the proposed RFID system has so many potential stakeholders, the issue of who should fund the system is complicated. One method of determining who should pay for the system could be based on the affordable loss principle, which suggests that an organization considering a new venture should base its decision not on expected returns, but rather on what it can afford to lose. Stakeholders with relatively large budgets could more easily absorb a failed attempt at improving their programs' performance and therefore might be better suited to fund new technological systems. In this case, maritime security and search and rescue organizations most likely have the greatest budget resources and might be good candidates for funding the monitoring system. Another option of determining who should pay is to conduct a pilot study to assess which of the many stakeholders would likely receive the most benefit from the RFID system.

In conclusion, an RFID-based monitoring system could work effectively as one layer in a multi-faceted small vessel monitoring program. An RFID monitoring system could help to protect our nation from small vessel threats while balancing our need for privacy, freedom of movement, and economic vitality. It could also assist in preserving our marine resources and in ensuring that U.S. waterways continue to be a rich and viable source of commerce, sustenance and recreation for years to come.

THIS PAGE INTENTIONALLY LEFT BLANK

ACKNOWLEDGMENTS

I would like to thank Dr. Nicholas Dew for his guidance and good cheer. His excellent teaching and enthusiasm for RFID served as an inspiration for this thesis. I also want to thank Bill Gates for sharing his expertise and providing extraordinary assistance.

The completion of this thesis would not have been possible without the generous and consistent support of Dr. Churchill Grimes, the director of the Fisheries Ecology Division of the Southwest Fisheries Science Center. Thanks also to Cindy Thomson, also of Fisheries Ecology Division, for her insight regarding economic issues in fisheries.

The proof of concept study included herein was made possible by the generosity of Savi Technology, a Lockheed Martin Company, located in Mountain View, California. Thanks to John Compisi for his willingness to support the experiment, and special thanks to engineer Bob Veiga for his invaluable contribution of time and RFID knowledge.

Last but certainly not least is my wife, Christine. Her endless patience and understanding allowed me to devote the necessary time to this thesis. More crucial yet, she was my insightful and indispensable first reader and editor. Thank you.

THIS PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION

Radio Frequency Identification (RFID) is a rapidly emerging technology that is viewed by many as technology's "next big thing." (Hildner, 2006) Because of its capability to detect, identify and track humans, animals or objects, possible RFID technology applications abound. Using RFID could bring benefits to several private and public sector organizations, and many are already exploring the ways in which they could use the technology for various monitoring purposes. (Dew, 2006a; Balkovich et al., 2005; Fusaro et al., 2004) However, concerns over how tracking capabilities and data might be misused are inherent to this type of technology. For this reason, it is paramount that potential applications of RFID be carefully analyzed before the technology is employed and related policies are implemented.

A. PURPOSE

This thesis investigates the many issues involved with one possible use for RFID technology – namely, an RFID system that would monitor small vessel movement. The thesis clarifies how the technology could be used by several key stakeholders: maritime security agencies, resource managers, and private citizen waterway users. Issues such as costs and benefits, privacy concerns, and public acceptance are explored. The thesis then analyzes the results of a proof of concept study conducted to gauge the feasibility of the proposed system. The study concludes with preliminary guidelines to assist agencies interested in utilizing RFID for small vessel monitoring on waterways.

B. PROBLEM

Using RFID technology to monitor small vessel movement on waterways could benefit many organizations and is likely cost effective. RFID is not a technology that needs to be further researched and developed, but rather it is an off-the-shelf product that could benefit a number of key stakeholders immediately. That said, it is necessary to study the costs and benefits to each stakeholder and to develop an effective implementation plan.

C. BACKGROUND

RFID technology is something like a more advanced version of a barcode that identifies and tracks objects using radio signals. Unlike a barcode, RFID does not require that an object be directly scanned; rather, it can identify tagged items anywhere within the range of its receivers. This allows RFID tags to be placed inside products and even animals and still be detectable from a distance. RFID is already used broadly in applications as diverse as monitoring cattle, preventing shoplifting, automating toll payment systems, and tracking juvenile salmon. The technology is increasingly being used by public and private sector organizations to monitor and study patterns of human behavior. (Hildner, 2006)

RFID technology relies upon small data storage devices called RFID tags. These tags store data on tiny silicon chips and can be attached to any object, person or animal. An RFID receiver can then send a radio signal to a tag and await a return signal from the tag, allowing the receiver to quickly identify or locate the tagged entity. Tags can be either passive (requiring no internal power source) or active (requiring a power source such as a small battery, allowing the tag to communicate with the reader within a greater range). RFID tags are relatively simple devices and only work within certain distances of their receivers; they cannot be located anywhere in the world like global positioning system (GPS) devices. As the technology has developed, tags have decreased in size and cost, making RFID technology viable for widespread commercial and governmental uses.

RFID technology dates back to techniques developed to differentiate between friend and foe aircraft during World War II. Development continued during the 1970's, when scientists at Los Alamos developed RFID tags to securely track vehicles carrying nuclear materials. This supply chain management application marks the genesis of the private sector's recent explosion into the RFID market. Lead by behemoths Wal-Mart and Target, corporations have set goals for their suppliers to use RFID technology on shipments, and many are already using RFID extensively for their own inventory management. (Wyld, 2005)

Though much of the current attention to RFID is focused on the private sector, the public sector has also benefited from RFID and has helped to advance this transformational technology. The Department of Defense's (DoD) supply chain mandate is in the process of integrating RFID into the world's largest and longest supply chain. The DoD's determination to incorporate RFID as a tool to help their mission has been categorized as the likely "tipping point" for RFID implementation throughout both private and public sectors in the United States. (Wyld, 2005) Other federal agencies incorporating RFID include the Food and Drug Administration (FDA) and the National Oceanographic and Atmospheric Administration (NOAA), among many others. (U.S. Government Accountability Office, 2005) The FDA plans to use RFID to ensure the availability, genuineness and security of the nation's prescription drugs, while NOAA implants RFID tags into fish to study migration patterns and survivability.

As the use of RFID systems becomes ever more prevalent in the public and private sectors, new ways of using the technology become increasingly viable. With that in mind, this thesis explores that possibility of using RFID to monitor small vessel movement on waterways.

D. METHODOLOGY AND FORMAT

To best understand the issues surrounding RFID as a possible tool for small vessel monitoring, this study draws upon social scientific approaches to studying emerging technologies, technology adoption, and surveillance and privacy.

This thesis relies on a combination of primary research methods and secondary data to examine the problem. By and large, there is an overwhelming flow of publications on this rapidly emerging technology. However, discussions from interviews and data collected from personal interactions fill in gaps that cannot be filled by the secondary research.

The first chapter of this thesis presents the proposed system of using RFID technology for small vessel monitoring. This chapter is followed by the heart of the thesis – a chapter devoted to each of the key stakeholders. The first stakeholder chapter examines the relevance of RFID to maritime safety and law enforcement agencies. This is followed by a chapter that focuses on the system's costs and benefits to resource managers (typically government agencies). The final stakeholder chapter highlights the impacts of the proposed RFID system on the private citizen boaters, drawing on examples of current RFID applications to explore issues of privacy associated with tagging boats for monitoring purposes.[1] Next, the shareholders' collective costs and benefits are weighed to assess the RFID system's potential value. The chapter investigates from where funding for a small vessel monitoring system could originate. The next chapter looks at a proof of concept study conducted by the author to assess the viability of the proposed RFID application on waterways. The thesis concludes with preliminary guidelines to be considered in creating an RFID-driven small vessel monitoring system.

[1] This subject must be examined thoroughly with any RFID tagging project, particularly one designed to track human movement patterns.

II. RFID VESSEL MONITORING PROPOSAL

RFID is a proven technology that is emerging as a viable way to improve many operations. This chapter considers how RFID technology could be used to improve monitoring of small vessels in the U.S. The chapter focuses on how an RFID system would work by doing the following:

A. Examining current vessel monitoring systems;

B. Outlining the details of the proposed RFID system; and

C. Exploring some technical requirements of the proposed RFID system.

A. CURRENT VESSEL MONITORING SYSTEMS

Although an RFID-based tagging system could be applied to all types of vessels, the focus of this proposal is on small vessels only, not ships. Methods of distinguishing between the two vary, but as a general rule, a boat can fit onto a ship, but a ship cannot fit onto a boat. Most ships already carry a monitoring system superior to an RFID system – the Automated Information Systems (AIS).[2] AIS ties into the many navigation systems aboard ships and broadcasts a ship's position, speed, heading, name, and VHF call sign at regular intervals via a VHF transmitter. While the AIS system works for ships, it is not feasible for smaller boats because of its high cost.

Although there is no monitoring system equivalent to the AIS for U.S. small vessels, methods of identification do exist. Currently, small vessels are either assigned numbers by state agencies (referred to herein as "undocumented vessels") or documented with the U.S. Coast Guard ("documented vessels").

[2] The International Maritime Organization's (IMO) International Convention for the Safety of Life at Sea (SOLAS) (which is the world's foremost treaty regarding maritime safety) "requires automatic identification systems (AIS), capable of providing information about the ship to other ships and to coastal authorities automatically, to be fitted aboard all ships of 300 gross tonnage and upwards engaged on international voyages, cargo ships of 500 gross tonnage and upwards not engaged on international voyages and passenger ships irrespective of size" (International Maritime Organization, 2007).

1. Undocumented Vessels

All non-commercial vessels and commercial vessels less than five net tons or less than 30 feet in length are considered undocumented vessels and are managed by the states. These undocumented small vessels are uniquely tagged with a state-issued permanent vessel registration number and a current registration sticker.[3] The unique numbers are typically painted or permanently attached to each side of the forward half of the vessel, and current registration must be affixed to the hull of the vessel, adjacent to the permanent registration number. The Department of Motor Vehicles (DMV) manages undocumented boat registration in the majority of states. In the remaining states, it is a parks division or a fish and game department that oversees the undocumented boat registrations.

2. Documented Vessels

Documented vessels are not numbered by the states and are titled by the U.S. Coast Guard. This class of vessels lies in between what would be considered recreational boats and ships. These vessels typically are of five net tons or more and are used in fishing activities, coastwise trade, towing or dredging.[4] As opposed to being numbered, a documented vessel can be distinguished by its name and hailing port. Some states require documented vessels to be registered with the state.

B. OVERVIEW OF PROPOSED RFID SYSTEM

This thesis examines the possibility of monitoring small vessel movement on waterways using RFID technology. While not as sophisticated as the AIS system utilized by some larger boats and ships, an RFID system would provide interested agencies with some level of capability to monitor vessel movement. Such a system would

[3] Federal code mandates that undocumented vessels with propulsion machinery must be numbered by the states. (United States Code, 2007) State requirements for vessel registration vary, but in most states, small unmotorized vessels such as canoes, rowboats, and dinghies do not need to be registered.

[4] Recreational boats of 5 net tons or more can be documented by the Coast Guard at the owner's discretion.

improve upon the current method to track the nation's 13 million registered small vessels, which relies on observing the adhesive stickers displayed on the vessels.

The proposed RFID system would be based on off-the-shelf technology – technology that has been utilized successfully in many other monitoring programs. Active RFID tags would be issued to small vessel owners, who would be responsible for affixing the tags to their boats (similarly to how they are currently responsible for applying registration stickers and numbers). These tags would be encoded with a unique identifier that would link to information that could include the owner's name, boat registration information, the vessel class and size (recreational powerboat, sailboat, commercial fishing vessel, research boat, etc.) and any other information deemed applicable. Receivers to interrogate these tags would likely be placed in narrow waterways that act as chokepoints (or bottlenecks), such as passes, inlets, bridge spans, and harbor entrances. As boats came into contact with a receiver's read field, their tags would be interrogated by an electromagnetic wave. Retrieved data would be processed with decoding software before being forwarded to an information system.

C. TECHNICAL REQUIREMENTS

Monitoring vessels with RFID technology is an intriguing concept in part due to RFID's simplicity. Only three components are required in any RFID system: the tags, readers, and an information processing system. The tags serve as unique identifiers for the objects to which they are affixed. The readers (often referred to as interrogators) constantly emit radio waves in search of passing tags. When a tag is interrogated by the reader's radio waves, the tag responds with its unique identifying signal. This radio wave signal is converted by the receiver into data and is passed on to the information processing system. The information system stores, filters, and categorizes this information.

The goal of an RFID-based small vessel monitoring program would be to approach a 100% read rate of boats passing through the bottlenecks where the readers are located. To accomplish this, active RFID tags would be affixed to the boats. Active tags are similar to passive tags in that they contain a chip, antenna, and packaging. In addition to these three components, active tags also contain an internal battery that continuously powers the tag. This continuous power leaves the tag always “on” and transmitting the information encoded in the chip. Despite always being “on,” the tag is only readable when it is in the field of the receiver.

Active tags, due to their onboard power supply, are effective over distances as far as several hundred meters. This enhanced read range would allow shore-based readers to effectively monitor boats at many bottlenecks on waterways. Assuming a read range of 200 meters, an RFID system could monitor a passage of water as wide as 400 meters using a receiver on each side of the waterway. In practice, the read range would not have to span the body of water so long as it captured the navigable portions of the water.

III. RFID FOR MARITIME SECURITY AGENCIES

This chapter examines potential uses of the proposed RFID system by maritime security agencies, or agencies involved in maritime safety, law enforcement and national security. Although each area is broad, the tasks involved are often performed by a relatively small number of agencies. This is particularly true at the federal level, where the United States Coast Guard considers maritime safety and security as two of their key missions. This combination of duties is also present at the state level, where the same marine patrol officer might rescue a vessel in distress, ticket a vessel for an expired registration, or confiscate a vessel for illegal contraband all in the same week. This chapter considers several ways an RFID small vessel monitoring system could improve safety, security, and enforcement on U.S. waterways and addresses the diverse concerns of these critical maritime security stakeholders.

A. SEARCH AND RESCUE

The United States Coast Guard (USCG) is the nation's most prominent waterway safety agency and is dedicated to eliminating "deaths, injuries, and property damage associated with maritime transportation, fishing, and recreational boating" (USCG, 2007a). In particular, searching for and rescuing missing vessels is one of the USCG's oldest and most valued missions. One of the key operational challenges of Search and Rescue (SAR) is the time and resources spent tracking false signals and alarms, wherein a vessel is reported – but is not in fact – missing. The actual cost of these false alarms depends on the number of assets deployed. For a USCG search and rescue mission, this could feasibly include the following expenses:

- $3,700 an hour for each aircraft afloat (several may be used in a single search);
- $1,550 an hour for each cutter;
- $300-400 an hour for small boats. (USCG, 2007b)

Though no report tallies the total cost of false alarms for all regions, a report published on a USCG website for Washington and Oregon offers insight into the cost of these false alarms. In this region alone, USCG response to false alarms cost taxpayers more than $2.6 million in 1999. (Office of Boating Safety, 1999) This figure is quite significant when one considers that Washington and Oregon had only 3.5% of U.S. registered boats in 1999. (USCG, 2000) Extrapolating this region's cost per boat yields a nationwide false alarm estimated cost for 1999 of over $74 million.[5]

The majority of the false alarms that triggered SAR activities were sightings of recreationally fired flares, hoax mayday (emergency) radio calls, and accidental emergency beacon broadcasts. However, greater than 5% of the false alarms involved overdue vessels that were subsequently found moored in a harbor. (Office of Boating Safety, 1999) These false alarms are not uncommon and originate from calls made by concerned friends or family to a SAR unit to report a vessel overdue. Despite the good intentions of such callers, false alarms create unnecessary work for SAR personnel and endanger lives (of rescuers and boaters in real peril) by needlessly deploying resources. As stated by the USCG's Canadian counterpart, "Overdue vessels trigger a very comprehensive SAR operation, involving the entire communications network, urgency broadcasts, air and marine resource tasking and police and harbour authorities. Overdue situations are often very difficult to resolve by SAR authorities, mainly because of time and lack of information" (Fisheries and Oceans Canada, 2007).

An RFID system could be of great help in eliminating the problem of search and rescue false alarms. It would allow the USCG access to accurate information regarding whether or not small vessels reported missing had returned to port, eliminating unnecessary deployments of resources. Furthermore, in the case of an actually missing vessel, RFID-gathered information could help USCG rescuers form a search radius based on the time the boat left the harbor and the speed of the vessel. An RFID system could

5 In 1999, 196,102 registered boaters in Oregon, 250,606 registered boaters in Washington and 12,738,271 total registered boaters in U.S. Total of Washington and Oregon divided by total boaters equals 3.5%. Cost per boat times total number of boats yields a false alarm estimate of over $74 million. Because this $74 million assumes that all SAR units incur the same cost as USCG units operating in Oregon and Washington, this calculation may overestimate the actual cost of false alarms to the USCG, since the coastal conditions of Oregon and Washington can be particularly harsh.

also be valuable to SAR during a more vast emergency situation, referred to by USCG as a mass rescue operation (MRO). (International Maritime Organization, 2003) For instance, if a major hurricane was coming up the Atlantic coastline, SAR units could determine the number and names of small vessels that left their moorings and were possibly in a dangerous position. A functioning RFID system would allow them to contact and warn vessels individually and account for their safety following the storm. To increase its accuracy in eliminating false alarms, the RFID system could be coupled with a video monitoring camera that would provide visual proof of vessels leaving or returning to the harbor.

B. LAW ENFORCEMENT

Law enforcement concerns on U.S. waterways include operating vessels without proper licensing or documentation, illegal fishing or other unlawful resource use, illegal transporting (especially of drugs and illegal immigrants), and vessel theft. Agencies such as the USCG and the NOAA Fisheries Office for Law Enforcement (as well as state and local enforcement agencies) are heavily involved in monitoring vessel activity to prevent and prosecute these crimes. The 2008 Federal Budget designates $1.72 billion for USCG law enforcement activities, which represents a significant portion (29%) of the USCG's annual budget.

An RFID system monitoring small vessels could be very beneficial to law enforcement agencies. By monitoring those vessels that pass by the RFID receivers, agencies could identify unregistered vessels (any vessel without a tag would be assumed to be unregistered), locate stolen vehicles, or track the movement of vessels whose owners were under surveillance. Strategic placement of RFID receivers could also allow agencies to detect when vessels entered restricted waters or areas that did not support the type of activity the vessels were meant to be conducting.

RFID systems have already been used for similar law enforcement purposes on land. An example of such a use can be found in Bermuda. In 2005, Bermuda's Transport Control Department hired 3M's Traffic Safety Systems Division to study and design an RFID-based system to automate registration and compliance of the island's 47,000 vehicles. The government's interest in an automated system was spurred by estimates that the nation currently loses $11 million every five years because they are unable to enforce vehicle-licensing requirements.

3M proposed a system in which all cars would carry a registration label and passive RFID transponder. Readers and a video-based vehicle detection system would be stationed at the island's main traffic junctures. If a car arrived at an intersection without the current RFID encoded registration, the system would photograph the car's license and a citation would automatically be issued to the owner. This system also would differentiate between passenger and commercial vehicles and could cite commercial vehicles operating in restricted areas during rush hour without further congesting the roads. (Wessel, 2007)

Following several years of research, the Bermudan government began implementing the system in May 2007. RFID tags are being placed inside vehicles in a manner similar to the RFID tags used for toll-road passes in the U.S. This vehicle registration system is quite similar to an RFID system that could improve enforcement of small boats.

C. HOMELAND SECURITY

Small vessel movement on U.S. waterways is also of concern to those agencies involved in national security, particularly the Department of Homeland Security. Because such a great portion of the nation is surrounded by water, monitoring the activities that take place on waterways is essential to protecting the U.S. from outside threats. As discussed at the Department of Homeland Security's National Small Vessel Security Summit in June 2007, vessels like those that would be monitored by the proposed RFID system may be one of the primary access points for those who wish to bring harm to the U.S. Because small vessels are less regulated than ships and large watercraft, it is easier for them to support illegal activity. Historically, organizations like Al Qaeda have used small vessels to smuggle weapons and launch attacks against naval vessels. Department of Homeland Security Secretary Michael Chertoff has also spoken of the potential for small vessels to transport into the U.S. weapons of mass destruction or the terrorists who would use them, as well as the potential for small vessels themselves to be used as improvised explosive devices (IEDs) to attack ships or port facilities. (Chertoff, 2007) At the summit, Secretary Chertoff repeatedly emphasized the importance of recognizing the possible threat of small vessels – not just container ships – as threats to national security:

> But I have to tell you that if all we do is worry about containers, it's as if we're locking the front door and we're kicking the back door wide open. Because there's also a concern that we have that someone might seek to smuggle a weapon of mass destruction into a seaport or between the seaports, not using a container, but using a commercial vessel, including a vessel that is below 300 gross tons.
>
> So if we're going to take this issue of maritime safety and security seriously, we can't only look at containers. We have to look at the whole range of methods in which someone might smuggle that weapon of mass destruction into the country. (Chertoff, 2007)

An RFID system to monitor small vessel movement could assist the Department of Homeland Security in managing the threat posed by small vessels. Used in conjunction with video surveillance, RFID could help track suspicious vessels and identify vessels without proper documentation. The system could also determine when vessels entered restricted or high-risk areas without permission. Policies that required small vessels to be equipped with RFID tags could also discourage small vessel threats by generating concerns of being identified or intercepted. At the most basic level, RFID tags on small vessels could be one element of a larger effort to create a security system for small vessels.

THIS PAGE INTENTIONALLY LEFT BLANK

IV. RESOURCE MANAGERS: AN RFID SOLUTION

This chapter examines how an RFID monitoring program could improve the forecasting abilities of resource managers. The potential impact of an RFID tagging system upon resource managers seems almost entirely positive, with the lone negative impact being that it requires a change in the status quo for managing aquatic resources.

A. BACKGROUND

Resource managers are tasked to ensure that the nearly 13 million boats on U.S. waterways operate in a sustainable manner. To accomplish this primary objective, resource managers must know where these boaters go and how often. They also are interested in knowing in which types of activities vessels are engaged. For organizational purposes, resource managers place all boaters into one of two broad categories – consumptive users and non-consumptive users. Consumptive users are primarily vessels engaged in fishing, while non-consumptive users are the remaining vessels not engaged extraction-based activities.[6] Resource managers strive to understand how these different users utilize waterways so that they can estimate their effects on various marine resources.

Many of these questions involving small vessel movement and activity are currently answered by data from surveys which ask boaters about their waterway use patterns. Unfortunately, these surveys are limited by a number of constraints.[7] The validity of survey research is always somewhat problematic; researchers can never be certain that survey responses accurately depict boating activities. As Chapman writes, "[i]t must be accepted that what we are collecting is people's answers to questions, which is not necessarily a true picture of their activities" (1990, p. 15). Survey validity is

[6] This classification is adapted from NOAA Technical Memorandum NMFS-NE-119, which states that "[s]ome argue that certain non-consumptive uses disrupt habitats, breeding patterns, or feeding patterns and should therefore not be considered non-consumptive." Like the NOAA memorandum, this thesis uses this term "for classification purposes only and not for descriptive purposes" (Kitts and Steinback, 1999).

[7] Thoroughly discussing the limitations of survey research is beyond the scope of this thesis, but a brief discussion of validity issues helps to illustrate why survey research alone is inadequate in the case of small vessel monitoring.

especially uncertain for surveys that ask questions that might reveal irresponsible or illegal behaviors; respondents are more hesitant to answer honestly if they feel they may embarrass or incriminate themselves with their answers. (Lensvelt-Mulders, Hox and van der Heijden, 2005; Rasinski et al., 1999) Thus, questions about water resource use may not be answered completely honestly. Careful attention to survey design, sampling technique, and data collection can improve the validity of survey research but require intensive manpower resources. Therefore, survey research – which, together with observation (also a labor-intensive endeavor) is typically resource managers' sole method of understanding how boaters use waterways – is not an ideal way of monitoring small vessel activity.

The next sections examine how key resource managers could benefit from an RFID monitoring system. The first section considers managers (primarily fisheries managers) who monitor the activities of consumptive boaters. This represents a significant water resource use category, as there are over 30 million recreational license holders nationally (many of whom fish from boats), along with thousands of commercial fishing vessels that land approximately 4.4 million metric tons of seafood valued at over $3 billion. (Van Voorhees and Pritchard, 2003; United States Fish and Wildlife Service, 2001) The second section considers managing boaters engaged in non-consumptive activities, which include various activities observing living ocean resources, such as whale watching, sightseeing, or scuba diving. The last section examines the management of cumulative environmental effects of human use on the nation's waterways and surrounding communities.

B. CONSUMPTIVE RESOURCE MANAGEMENT

RFID technology is not entirely new to fisheries managers, as RFID tags have been implanted in fish for tracking purposes for years. However, using RFID small vessel monitoring data to estimate the effects of boating on marine resources has not yet been explored. The next sections look at how an RFID system could enhance management of the recreational and commercial fishing fleets.

1. Recreational Fisheries

In a 2004 *Science* article, Coleman et al. convey the message that for many stocks considered overfished, recreational anglers contribute a higher percentage of the catch than commercial fishermen. They cite that the recreational landings for boccacio, a “Species of Concern” occurring in California waters, amount to 87% of the total catch. This example illustrates that fisheries managers need to accurately assess the impacts of recreational fishermen when considering stock assessments and policy decisions.

Unfortunately, fisheries managers struggle to pinpoint the effects of recreational fishing on fish populations. The Marine Recreational Fisheries Statistics Survey (MRFSS), the nation’s primary tool for estimating the impact of marine recreational fishing on marine resources, is widely criticized as being inadequate. (National Research Council, 2006)

The MRFSS has served as the primary source of recreational fishing data since it was implemented by the National Marine Fisheries Service (NMFS) in 1979. The MRFSS relies on two primary tools to gather this fisheries dependant data.[8] The first is an onsite component where the investigators intercept recreational fishermen either on the water or where they access the water and ask them to participate in a survey. The survey gathers data regarding the species, sizes and location of the fishes captured. This data is used in concert with telephone surveys. These surveys are directed at households located in coastal communities and are used to collect recreational fishing effort data (or data indicating how much fishing took place, regardless of yield), specifically effort within the past two months.

In 2006, The National Research Council (NRC) concluded that the MRFSS was not an acceptable source of data for fisheries managers, stating that it utilized ineffective theory and methods. (An example of methodological problems with the MRFSS is that data are typically collected at times convenient for the employees that gather the data. Data collection occurs during daylight hours and focuses on the standard Monday to

[8] “Fisheries dependent data” refers to data collected from fishermen and fish processors. This differs from fisheries independent data, which result from research conducted by fisheries scientists and personnel.

Friday work week, which does not necessarily coincide with the most popular times for recreational fishing.) The problems with the MRFSS even caught the attention of recreational fishing publications, one of which noted that the NRC's findings were not new:

> This is not the first time that MRFSS has been critically reviewed. In fact, a minimum of 4 studies have evaluated recreational data collection programs in recent years, including two NRC reports issued in 2000 and 2002, both of which include ways to make improvements. Since that time, nothing has been done to significantly improve MRFSS or the estimates it produces. (*Marlin*, 2006)

The NRC recommended that the MRFSS be "completely redesigned" (National Research Council, 2006).

Using RFID in fisheries management could improve the accuracy in recreational fishing data. Managers would no longer have to rely on survey data to reveal when fishing boats leave and return to harbors, as affixing RFID tags to boats would allow for automatically monitor such activity. Comparing survey data to RFID data could allow fisheries managers to test the validity and reliability of survey instruments; such comparison could provide information to help craft and conduct surveys more effectively. Data generated by an RFID system could also validate logbooks and other forms of self-reported data.

2. Commercial Fisheries

Commercial fishing is also an important consideration for fisheries managers. In general, it is easier for managers to monitor commercial fisherman, who are typically required to document information about their activities (including port of departure, gear type, time at sea, and fish caught). Fisheries managers gather data through methods such as landing receipts indicating what fish were delivered by fishermen and logbooks that record commercial vessels' activities. Although these methods should provide managers with more reliable data than is available for recreational fishing, they are still flawed. Landing receipts show only when fish were delivered and reveal nothing of how much time was spent at sea pursuing those fish. Logbooks for each fishing trip may not be completely accurate (or may not be filled out at all).

Some U.S. fisheries have a vessel-tracking program that accounts for each vessel's position every hour of each day. This system, referred to as Vessel Monitoring System (VMS), sends latitude and longitude coordinates via satellite to fisheries enforcement officials every hour, whether the fishing vessel is at sea or in port. The intent of the system is to ensure that the fishing boats do not fish in closed and protected areas. This VMS system is currently employed in the Atlantic, Gulf of Mexico, and Pacific for a variety of fisheries and seems to be slowly gaining momentum as an accepted tool for managing fisheries. Although the VMS system is capable of providing useful information, equipping vessels with VMS components is rather expensive (around $3,500-3,900 per vessel, along with $480-660 in annual maintenance fees).

As with recreational fisheries, an RFID monitoring system for commercial fishing vessels could supply fisheries managers with valuable data. RFID could validate information about landings, time spent at sea, and other trip details that is otherwise only available from landing receipts and logbooks (which are limited and unreliable sources of data). An RFID system could complement VMS systems where they are used, because it could provide more specific information about when vessels passed through certain points (beyond VMS's hourly updates). RFID components are also significantly less expensive than VMS components, so supplementing or replacing VMS systems with RFID systems could be a cost-effective option for many fisheries.

C. NON-CONSUMPTIVE RESOURCE MANAGEMENT

Recreational boating for purposes other than fishing is an ever-growing leisure activity in the U.S. Whale/nature-watching, diving, sightseeing, and other non-consumptive activities account for significant vessel usage on public waterways. Although non-consumptive boating activities are not meant to have a direct effect on fisheries and other resources, they are still of great interest to resource managers, such as managers of the nation's marine sanctuaries, who monitor their impact upon specific resources, as well as the overall condition of marine ecosystems. Like recreational fishing vessels, non-consumptive recreational vessels are currently monitored largely through observational or survey data.

An RFID system could provide benefits to non-consumptive resource managers that are similar to those provided to fisheries managers. By generating precise data about recreational boaters' use patterns, RFID could be used to verify survey and self-reported data, as well as to improve or replace current data collection methods.

D. ENVIRONMENTAL MANAGEMENT

The number of registered vessels on waterways has steadily increased over the past two decades. (USCG, 2006) This trend in boat growth is likely to continue as U.S. coastal populations continue to grow. (Crossett et al., 2004) These additional boaters force coastal managers to balance the benefits of economic growth with the strains of increased boaters on coastal waterways. An RFID monitoring system could provide decision makers with use pattern data to better determine the impacts boaters have on waterways. Once the patterns are better understood, the monitoring system could potentially facilitate new and innovative ways of managing waterways.

For instance, if managers determined that a sensitive waterway was too crowded, the RFID system could be used to limit the vessels in the area. Boats could be charged daily use fees when they traveled into a designated limited access waterway just as cars are charged when they travel on toll roads. The fees, which would have to be set by economists, would ideally limit the number of boats in sensitive areas by creating financial disincentives. Fees would vary depending on the demand by boaters to use the particular waterway, the waterway's boater carrying capacity, the season, and the day of week. Fees collected by the system could be used to help ensure the waterway's long-term health as well as pay for the cost of the RFID system.

Charging boaters for access to waterways is not novel and is commonly utilized by national, state and local parks as well as private marinas. In many cases, these organizations collect launch fees from boats accessing a waterway. Although this controls the number of boats launching from the ramps and therefore indirectly limits the vessels in waterways, it does not affect boaters accessing the waterways from outside the area. For example, a boat from a private marina could use a waterway within a state park on a weekly basis without ever compensating the park. While these current payment mechanisms may effectively keep boats at a sustainable level on waters, the system may not be equitable. Also, by encouraging “free riders” (boaters that consume more than they contribute) the current system could prove problematic if boat use exceeds a sustainable level.

Use fees to protect sensitive waterways are only one way in which environmental decision makers could use an RFID-based small boat monitoring system to manage waterways. It is likely that better understanding how often, when, and how many vessels utilize waterways would better highlight potential environmental problems and possibly more effective management solutions.

THIS PAGE INTENTIONALLY LEFT BLANK

V. RFID AND WATERWAY USERS – PERSONAL BENEFIT VS. PRIVACY ISSUES

Private citizens using U.S. waterways comprise another stakeholder group of an RFID system to monitor small vessels. As is the case for maritime security agencies and resource managers, users could benefit in several ways from this system. User safety and boat security could be enhanced through the USCG's improved ability to perform their duties. Stolen vessels are more easily located if they have RFID tags hidden onboard. By storing payment information, RFID tags could also simplify and automate paying launch fees and other charges associated with using harbors. Tags could also consolidate registration and license information in a convenient and waterproof manner, saving users the trouble of tracking and protecting various paper documents.

RFID is already used extensively to benefit private citizens in electronic toll collection (ETC). By enrolling in ETC programs, citizens can have tolls automatically debited from a prepaid account, rather than having to stop and pay a cash toll. This is achieved by equipping enrolled vehicles with RFID tags and toll collection stations with RFID readers. Vehicles pass through specially designated ETC lanes, which either feature automated gates or allow the enrollee to pass through the toll collection station at full interstate speed. (Swedberg, 2006) This technology often saves users' time and eliminates the hassle of having the correct change at each toll station. It can also provide enrollees with a psychological benefit by giving them the impression that their commute time has been significantly decreased (regardless of the amount of time actually saved).

For the agencies and management organizations described in the previous two sections, an RFID system to monitor small boat movement on waterways is largely advantageous, with cost and other administrative challenges being the primary potentially negative impacts. But another concern exists for waterway users – privacy. Despite the many potential benefits, there are privacy issues inherent in any use of RFID involving humans, and RFID tags on boats are no exception. Issues of privacy (not cost or difficulty of implementation) would likely be the largest obstacles to monitoring boats with RFID tags. Addressing these privacy issues is a key to developing and implementing an RFID system.

A. VESSEL MONITORING CONCERNS

1. Tracking

Because RFID systems identify or record the location of a tagged object or person when in the field of a receiver, concerns over tracking and monitoring can exist. This issue has emerged in regard to RFID tags in consumer products. The possibility that an individual's behaviors (e.g., shopping habits, product preferences, use patterns, etc.) could be monitored by corporations and used for targeted marketing or other more invasive purposes has been frequently noted in recent years. (Albrecht and McIntyre, 2005; Baard, 2004) This type of concern also extends to the government using RFID, as some fear that government agencies might use RFID tags to surreptitiously monitor citizens' private activities. Organizations like the American Civil Liberties Union (ACLU) and Privacy Rights Clearinghouse have highlighted the possibility of privacy violations through using RFID tags in passports and government-issued ID cards. (ACLU, 2004; Privacy Rights Clearinghouse, 2003) In the case of small vessel monitoring, boaters may be concerned about the government's ability to track their boating behaviors and movements on the water.

2. Profiling

Another concern is using RFID in government profiling. It is possible that aggregating RFID data (and connecting it, most likely, with data gathered by other government sources), could provide a profile of an individual and his/her activities. This profile could then link the individual to suspicious or criminal groups or activities. This is a particularly sensitive privacy concern because the appropriateness of profiling for race, ethnicity and national origin has been widely debated in recent years. (ACLU, 2006; U.S. Government Accountability Office, 2005) Monitoring small vessels with RFID could possibly be viewed as contributing to profiling. An example of this might be aggregating data about boat owners whose boats have frequently been near a major bridge. This information could then be connected to other government data (such as intelligence data, criminal records, or racial/ethnic identification) and used to create profiles of these boat owners.

3. Secondary Uses of Information

Concerns over secondary uses RFID-generated data may also arise. As the U.S. Government Accountability Office (GAO) noted in a 2005 report, “information collected for one purpose tends over time to be used for other purposes as well. This has been referred to as ‘mission’ -or ‘function-creep’” (U.S. Government Accountability Office, 2005, pp. 21-22). Data collected with RFID systems are often entered into databases. It is possible that these databases might be “mined” by various government agencies (other than the agency that originally collected the information) and used for other purposes. Therefore, the information gathered by RFID systems might threaten individuals’ privacy in ways that have nothing to do with the intended purpose for collecting the data. One example of a possible secondary data use from the proposed RFID system (beyond its original intended use) could be vessel speed monitoring. Waterway law enforcement agencies could monitor a vessel’s speed by noting the time it takes for it to pass between two receivers. This data could then be used to issue a speeding citation.

4. Unauthorized Access

Unauthorized access to and use of RFID data could also violate privacy. If data are not sufficiently secured or encrypted, it is possible that hackers, marketers, foreign governments, or other organizations could access and misuse individuals’ personal information. An example relevant to RFID use on waterways might involve marketers or boating or fishing equipment suppliers. If these groups were able to intercept data gathered about boat owners and their boating behaviors, they could subject targeted boaters to invasive marketing tactics.

5. Loss of Anonymity

A more general privacy concern that some find troubling is the perceived loss of anonymity that might result from RFID systems. The mere idea that one's private activities and behaviors might become "data" that are monitored or scrutinized without one's knowledge is a violation of privacy to some, even if those data are never put to any use. This can be particularly true in regard to the government. As stated in a 2002 GAO report, "[p]eriodic public surveys have revealed a distinct unease with the potential ability of the federal government to monitor individuals' movement and transactions" (U.S. Government Accountability Office, 2002, p. 115). Because RFID could provide opportunities for the government to track or monitor private citizens' behaviors, it is sometimes characterized as a dangerous or threatening technology, regardless of how it is being used or how the data it generates is managed or secured.

B. SOCIOLOGICAL CONSIDERATION OF SURVEILLANCE AND PRIVACY ISSUES

1. The Panopticon Concept

To understand why the public might feel a "distinct unease" about using RFID in general, and about government RFID use in particular, it is useful to consider some basic sociological concepts about the issues of surveillance and privacy. One such concept is the "panopticon." Developed by the philosopher Jeremy Bentham in the late 1700's, the panopticon concept originally referred to a plan for a semi-circular prison that made it possible for all prisoners to be monitored from a central surveillance point at all times. The panopticon concept over time came to represent a more general notion of a central authority (usually the government) with broad surveillance capabilities, through which it exercises social control over its citizens. (Fox, 2001) Part of the power of a panoptic government is that citizens perceive themselves to be under surveillance at all times, even if this is not the case. This perception causes citizens to exercise self-discipline and control over their own behaviors, thereby lessening the need for the government to enact overt means of social control. (Fox, 2001) Thus, in a panoptic society, people may be submitting to the will of the government without even realizing it, based on their feelings of being continually watched or monitored by the government.

Although the general public is not very familiar with the panopticon, the ideas represented by the concept are often popularly associated with George Orwell's novel *1984*, and with its concept of the government as a "Big Brother" which is watching citizens' every move. (Fox, 2001) Images like that of the "Big Brother" suggest that government possession of data about private citizens is a nefarious enterprise and something to be feared: "At one time the concept of 'surveillance' was confined narrowly to policing or spying. Now it encompasses the numerous other settings in which personal data are being collected by the governmental and private sectors as part of their crime prevention, revenue-raising, risk management, resource allocation and marketing objectives" (Fox, 2001, p. 266). "Surveillance" becomes a dirty word that suggests the exertion of social control and the invasion of personal privacy.

2. Public Concern of "Spychips"

Images that promote the notions of the panopticon and of an ever-watchful "Big Brother" in American society are prevalent in relationship to RFID. Among the first Google hits that occur after entering the search term "RFID" are a number of web sites that warn of the many perils of RFID tagging and data collection. One such site promotes a popular book entitled *Spychips: How Major Corporations and Government Plan to Track Your Every Move with RFID.* (Albrecht and McIntyre, 2005) This book and its accompanying web site present RFID technology as a malevolent tool of greedy corporations and invasive government agencies, both of which are trying to rob American citizens of their right to privacy. They warn of RFID-tagged Levi's that will reveal their wearers' every move, and of tags that can be implanted underneath human skin to track wandering patients or to keep tabs on foreign guest workers. (Spychips.com, 2006; Albrecht and McIntyre, 2005) References to "Big Brother" and RFID proliferate on Spychips.com, as well as in many other easily accessible locations on the Internet. (Electronic Privacy Information Center, 2006; McCullagh, 2003) Examples of RFID systems being used to track individuals' private activities are already emerging. One features electronic toll records being used in divorce court to help prove infidelity. (Newmarker, 2007)

The prevalence of this type of information in the public sphere suggests that RFID technology is already being framed in a negative light, due to strong associations with potential misuses and privacy violations. This framing and the associated potential misgivings of the public must be acknowledged by any organization intending to implement RFID systems – including those interested in monitoring small vessel movement on waterways. As one analyst writes, "[t]he gathering storm against RFID tags may soon outpace positive efforts and make product-level RFID tagging taboo. RFID makers and users should take a time-out from their technical discussions and start talking more with the public about what's going on" (Cline, 2004).

C. ADDRESSING THE PUBLIC'S PRIVACY CONCERNS

1. Protective Legislation

Despite the privacy concerns involved in using RFID, the technology does offer many potential benefits to both the organizations wishing to use it and to private citizens. For this reason, it is important to address the public's concerns and to offer possible solutions to the problems RFID may seem to pose. For the public to accept the use of RFID, despite the negative light in which it is often popularly portrayed, it is necessary for them to be educated about how the technology works and the existing legal framework that regulates its use and provides for RFID data security. This framework includes the Privacy Act of 1974, which

> limits federal agencies' use and disclosure of personal information. The act's protections are keyed to the retrieval of personal information by a 'name, or the identifying number, symbol, or other identifying particular assigned to the individual'…The Privacy Act generally covers federal agency use of personal information, regardless of the technology used to gather it. (U.S. Government Accountability Office, 2005, pp. 22-23)

The E-Government Act of 2002 helps to ensure that RFID systems' data collecting practices are acceptable by providing "a means of evaluating whether or not to collect information based on privacy concerns." (U.S. Government Accountability Office, 2005, p. 23) Additional RFID-specific regulation on the federal, state, and local levels could further protect individuals from privacy violations; some states have already begun to pass this type of legislation. (Hildner, 2006; Spychips.com, 2006)

2. Establishing Public "Buy-in"

Citizens should also understand the potential personal benefits of using RFID systems. Although privacy concerns may exist, the public may want to weigh the "pros and cons" of RFID system implementation before they decide whether or not to support it. While the idea of being "watched" may be bothersome, an individual may feel that the benefits of an RFID system outweigh privacy concerns. In other words, there are times when "citizens are willing to abandon elements of their privacy in order to gain access to highly desired private sector services, or because it is otherwise in their interests to do so" (Fox, 2001, p. 266). An example of this is enrollment in ETC systems. While ETC systems certainly have public benefits (such as controlling traffic congestion), it seems likely that enrollees focus almost entirely on the benefit it brings to them personally when they think about ETC. With such an obvious personal benefit, ETC may not arouse as much concern about privacy as an RFID application that is more clearly directed toward a public advantage. It may be necessary for agencies to study the motivations and priorities of those who will be affected by RFID systems to increase "buy-in" to using those systems. (Dew, 2006b) Another example of an organization trying to implement an RFID system by appealing to private citizens' desire for personal benefit can be found with Mini Cooper automobiles. BMW has begun distributing devices equipped with RFID tags to willing Mini Cooper owners**.** Receivers on billboards detect the tags in oncoming vehicles and use information encoded in the tags to communicate personalized messages to the drivers. For instance, a driver named Jim might see a "Motor On, Jim!" banner flash onto the billboard as he drove by. Although BMW benefits by creating a unique marketing tool for its product, Mini drivers who chose to participate likely do so because of the benefits they feel they will gain (such as enjoyment of something novel, or a sense of community with other Mini owners). As one participant states, “It is something different…I am also a tech geek, so any chance to demonstrate this is always welcomed” (O’Connor, 2007). In the case of RFID for small vessel monitoring, focusing on the benefits to private users discussed above (including increased safety, boat security, and convenience in paying fees and keeping track of documentation) may convince boaters to support implementing an RFID system.

Another way to address citizens’ privacy concerns is to create an “opt-in/opt-out” structure, which would allow individuals to decide for themselves whether they wanted to participate in an RFID system. (U.S. Government Accountability Office, 2005) Allowing citizens to choose can help to build trust in the system and increase their level of comfort with the technology. (Fusaro et al., 2004) This could be particularly relevant for the proposed RFID system. Although 100% participation would be ideal, a smaller percentage of voluntary participation would still provide maritime security and resource management agencies with valuable data that would otherwise not be available.

VI. COST CONSIDERATIONS

A. DETERMINING WHO SHOULD PAY FOR THE SYSTEM

With the potential for so many groups to benefit from RFID-based small vessel monitoring, it is important to examine who should pay for such a system. First, the possible funding sources for the necessary RFID tags will be addressed, followed by discussion of several approaches to determining who should fund the remaining RFID system components.

1. Funding for Tags

Because the proposed system requires that each small vessel be equipped with an RFID tag, how these tags will be paid for must be addressed. In the early stages of implementation, existing state or local annual boating and boat ownership fees might be an effective funding source. These fees vary greatly in and between the states but in general are greater than the cost of the approximately $30 RFID tag. Because tags could last as long as five years, it seems even more reasonable that state or local agencies could assume the cost of them initially.

If state and local agencies were unable to cover the cost of the tags (because their boating fee income was earmarked for other important purposes), several other options for tag funding exist. The cost of the tags could be included in or added to other state or local fees, such as fishing licenses or other use fees associated with small vessels. Alternatively, boaters themselves could directly pay for the tags. This option would likely be unpopular with small vessel owners and might reduce the chances that the RFID system would receive public support (as discussed in the previous chapter).

2. Funding the System

a. Affordable Loss

One key aspect in determining who pays for the rest of the RFID-based monitoring system for small vessels is to examine the different stakeholders' affordable loss. According to the affordable loss principle, an organization considering a new venture should base its decision not on expected returns, but rather on what it can afford to lose. As Sarasvathy (2006) writes, "[t]o calculate affordable loss, all we need to know is our current financial condition and a psychological estimate of our commitment in terms of the worst case scenario" (p. 1). If an organization determines that it can withstand whatever hardships might accompany the worst possible outcome, it should go forward with the new venture. In the case of an RFID-based water use monitoring system, some stakeholders are forced to be conservative when it comes to adopting new technologies because their budgets are relatively small. Conversely, a stakeholder with a relatively large budget could survive a failed attempt at improving its program's performance. According to the principle of affordable loss, this type of stakeholder could reasonably pay for an RFID monitoring project.

b. Stakeholder Resources

Figure and Table 1 illustrate the differences in funding levels of some of the key stakeholders discussed in the previous chapters (in particular, those programs of NOAA and USCG that are likely to benefit from an RFID small vessel monitoring system). Although NOAA programs could certainly benefit, the agency receives only 13% of the total funding for those maritime security/resource management programs that would likely benefit from introducing an RFID monitoring system. Conversely, USCG receives 87% of the funds available for these programs (see Figure 1 and, for greater detail, Table 1). While it can be argued that a larger budget could be equally tight on funds as a smaller one, an agency with a larger budget could likely more easily absorb a failure and is therefore less risk averse, according to the principle of affordable loss. In this case, USCG may be better positioned to fund an RFID small vessel monitoring system than NOAA.

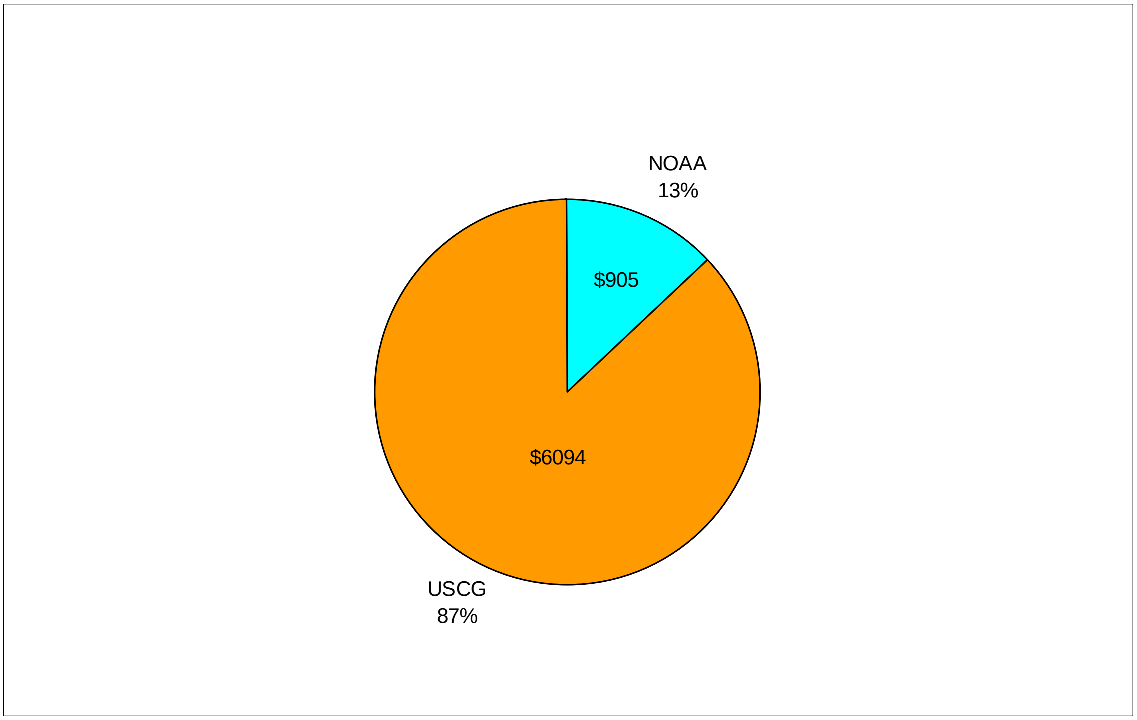

Figure 1. Average Funding (2006-2008, in millions) for USCG and NOAA Programs Likely to Benefit from RFID

Table 1. Average Funding by Program (2006-2008) for USCG and NOAA Programs Likely to Benefit from RFID

	Program	Average Funding (in millions)
NOAA	NMFS	$648
	Ecosystem Research	$211
	Protected Areas	$46
USCG	Migrant Interdiction	$570
	Defense Readiness	$608
	Drug Interdiction	$1401
	Marine Safety	$781
	Port/Waterway/Coastal Security	$1821
	Search and Rescue	$913

c. Funding Based on Benefit Received

Another approach to funding suggests that whichever organization derives the greatest benefit from the system should pay for it. Although this approach seems reasonable, it would likely be difficult to implement in the case of the proposed RFID system. As discussed in detail in the previous chapters, an RFID-based system tracking small vessels on waterways would likely benefit several stakeholders, including maritime security and resource management organizations. Although various tools can be utilized to forecast the benefits to different stakeholders, it is not possible to fully predict the impact of the system. Once implemented, an RFID system could prove more or less valuable than expected for various organizations and functions.

The data generated by the RFID system could also challenge organizations' previous assumptions to the point of revealing new applications for RFID monitoring. For instance, an RFID monitoring system could reveal that actual use patterns in small boats do not resemble the patterns currently used in models based on survey data. This knowledge could change a resource management organization's interest in small boat activity (as their theories about small boats' impacts on marine resources change).

An example of an RFID system changing how an organization approaches an area of study can be found in marketing research. A 2005 Wharton School study utilized RFID-equipped shopping carts to track the paths taken by shoppers within supermarkets. (Larson et al., 2005) The study found that shoppers traveled through supermarkets much differently than had been assumed. This discovery was noted to have "the potential to change the way retailers in general think about customers and their shopping patterns" (*Knowledge@Wharton*, 2005). The data generated through this RFID tracking system could lead marketing researchers to reevaluate how they approach their work and could prompt marketers and retailers to explore different ways of appealing to consumers. The findings of this study suggest that data gathered by RFID monitoring systems might challenge assumptions about many types of human behaviors. As Dew (2006a) writes in reference to using RFID to monitor military contractors,

> What reason do we have to believe that there is any less “widely accepted folklore” (Larson et al., 2005) about contractor behavior than there is about shopper behavior? If RFID tagging of shopping carts can help reveal empirical data on true shopper behavior, isn’t it also at least plausible to think that it can help reveal empirical data on true contractor behavior? (p. 20)

In the case of the proposed RFID system, the data it generates may reveal entirely new ways in which the system could be used. Therefore, because the short and long term uses of an RFID small vessel monitoring system are so difficult to predict, a benefit-based funding approach seems inadvisable in the initial stages of the project.

3. Pilot Project

One option for agencies interested in sponsoring an RFID system would be to initiate a pilot project. Since RFID is a fully developed off-the-shelf technology, funding agencies could work with a private corporation already working on RFID monitoring projects. A company with intrinsic interest in the full funding of the project could assist in a pilot project in the hope of leveraging a successful project into a fully funded contract. By capitalizing on a corporation’s interest in securing a government contract, an agency could further reduce its risk and affordable loss by testing an RFID system’s potential in the field.

THIS PAGE INTENTIONALLY LEFT BLANK

VII. PROOF OF CONCEPT STUDY

To ensure that the proposed small vessel RFID system was feasible, a proof of concept experiment was conducted. The experiment measured the effectiveness of readily available off-the-shelf RFID tags provided by Savi Technology, a Lockheed Martin Company.

A. STUDY SITE

The proof of concept study was conducted at the entrance to the Santa Cruz Small Craft Harbor in Santa Cruz, California. This site was chosen because of both its similarity to many of the nation's harbors and its close proximity to the researchers involved. The harbor berths approximately 1250 vessels, with additional boat traffic from launch ramps that are used approximately 19,000 times each year. (Santa Cruz Harbor, 2007) The study was conducted at a time of increased weekend traffic to ensure realistic conditions.

Rock jetties extend from the beach on each side of the harbor and are approximately 91 meters apart at the harbor entrance. The harbor dumps into the northern portion of Monterey Bay, and vessels returning to the harbor enter on a north/northwest course and within 50 meters are heading due north. A satellite image of the site can be viewed in Figure 2.

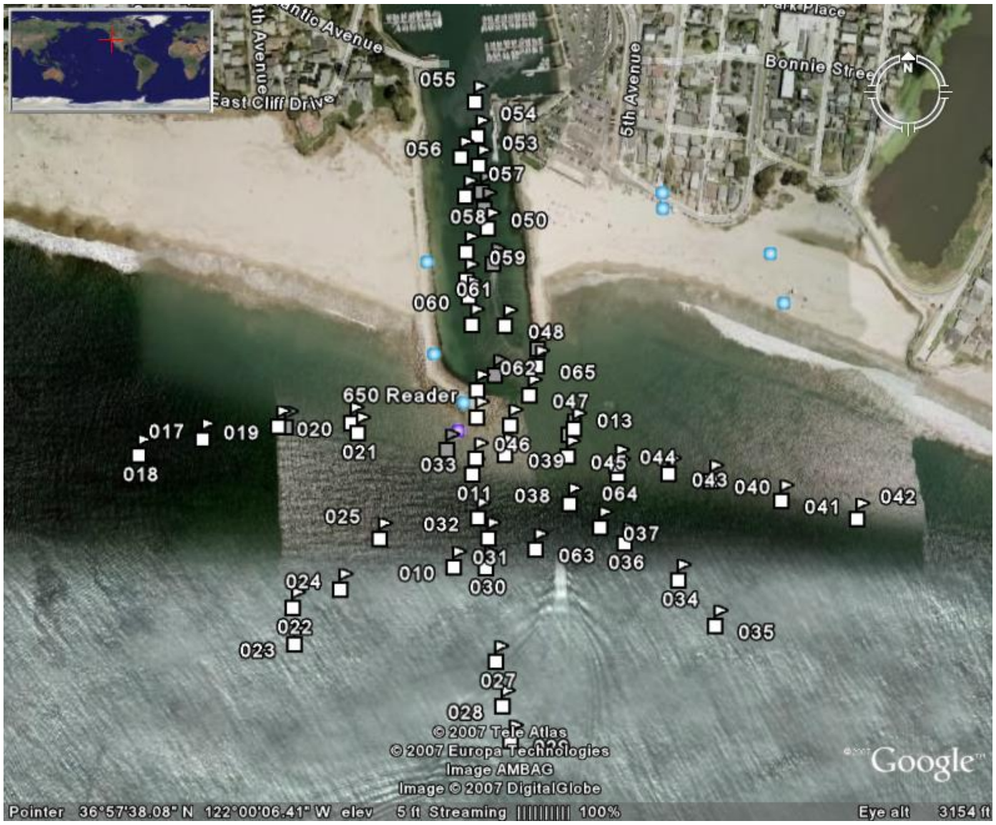

Figure 2. Aerial View of Santa Cruz Small Craft Harbor (Flagged points represent the locations of vessels during interrogation by the receiver.)

B. STUDY EQUIPMENT AND SET UP

The active RFID tags used in this study were SaviTag ST-654 models. These ultra high frequency (UHF) tags operate at 433 MHz with an advertised range of approximately 91.4 meters (tag dimensions: *L*=15.9 cm, *W*=5.4 cm, *H*=2.9 cm). This model of tag was designed to track containers, vehicles and other large objects in inclement environments. (Savi Technology, 2007b.)

The tags were placed at different heights and orientations in two small vessels. The first vessel tagged was a 3.0 meter polyethylene sea kayak (Figure 3). The tag was placed parallel to the length of the vessel at the base of the kayak’s hull, approximately 7.6 cm beneath the surface of the water. Eight active tags were also placed on a 5.8 meter fiberglass small boat (Boston Whaler Guardian) (Figure 4). These tags were placed at different heights and orientations, as depicted in Table 2. Tags were placed on the small boat in both realistic positions and positions that would test the reader's ability to deal with interference and penetrate fiberglass.

Figure 3. Sea kayak equipped with RFID tag.

Figure 4. Small vessel tagged with eight active RFID tags at different heights and orientations

Table 2. Tag Locations

Tag	Total Hits	Height above sea level (cm)	Orientation	Facing	Position Description
1	37	228.6	Horizontal	Forward	To post above center console
2	23	221.0	Vertical	Forward	To post above center console
3	17	121.9	Horizontal	Forward	At base of windshield
4	16	127.0	Vertical	Forward	At base of windshield
5	16	27.9	Horizontal	Aft	Inside bow rail
6	11	38.1	Vertical	Aft	Inside bow rail
7	9	22.8	Horizontal	Aft	Inside center console
8	4	81.3	Horizontal	Above	On seat

The receiver used for this study was a Savi Fixed Reader SR-650. This fixed reader is designed to monitor tags in yards and terminals at a distance of greater than a 100 meter line of sight radius. (Savi Technology, 2007a) The receiver was placed within 10 meters of the Walton Lighthouse on the western jetty of the harbor and positioned approximately 12.2 meters above sea level. (A tide change caused the exact height to vary by 1 meter.) A laptop computer was used to monitor and control the receiver.

C. METHODS

The vessels departed and approached the harbor entrance at five different angles covering 180 degrees. This method created a fan pattern of departures and approaches to the harbor that can be viewed in Figure 1. The purpose of this patterned approach was to determine if read rates and ranges were affected by the orientation of the boat to the receiver.

Additional read rates and ranges were taken within the harbor to ensure that read rate and range remained consistent. Effort was taken during these initial departures and approaches to maintain a vessel speed of approximately 5 knots. The final trials during the survey intended to mimic the behavior of a typical fast boat arriving and departing the harbor. The vessel's approach speed of 30 knots was quickly slowed to 5 knots upon entering the harbor, and conversely a departing speed of 5 knots was quickly increased to 30 knots during departure.

The operators of the small vessels took a GPS fix simultaneous to each interrogation by the receiver. (Handheld radios were used for communication between the receiver operator and boat operators.) These fixes, along with read data captured by the laptop, were imported into geographical information system (GIS) software and used to calculate range rates of the tags.

D. RESULTS

The tag placed in the bottom of the sea kayak was detected in each of three tests up to 105 meters from the receiver. The tag was not detected in tests conducted at 170 and 110 meters. On the small boat, the receiver detected each of the eight tags at least once on each approach and departure from the harbor. One tag was read at a distance of 354 meters from the receiver, but significant declines in read rates occurred at 160 meters, as shown in Figure 5. Figure 6 illustrates the read rates of the four tags positioned highest above sea level, and Figure 7 shows the read rates of the four lowest tags.

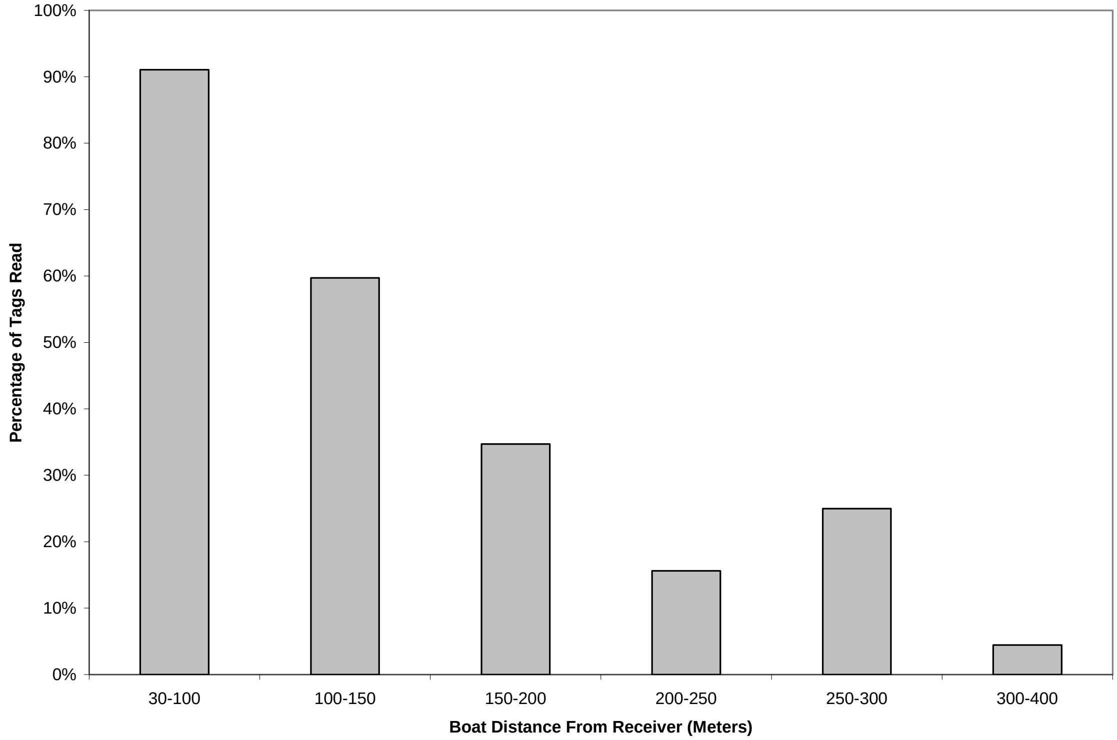

Figure 5. Small vessel read distances (Eight tags)

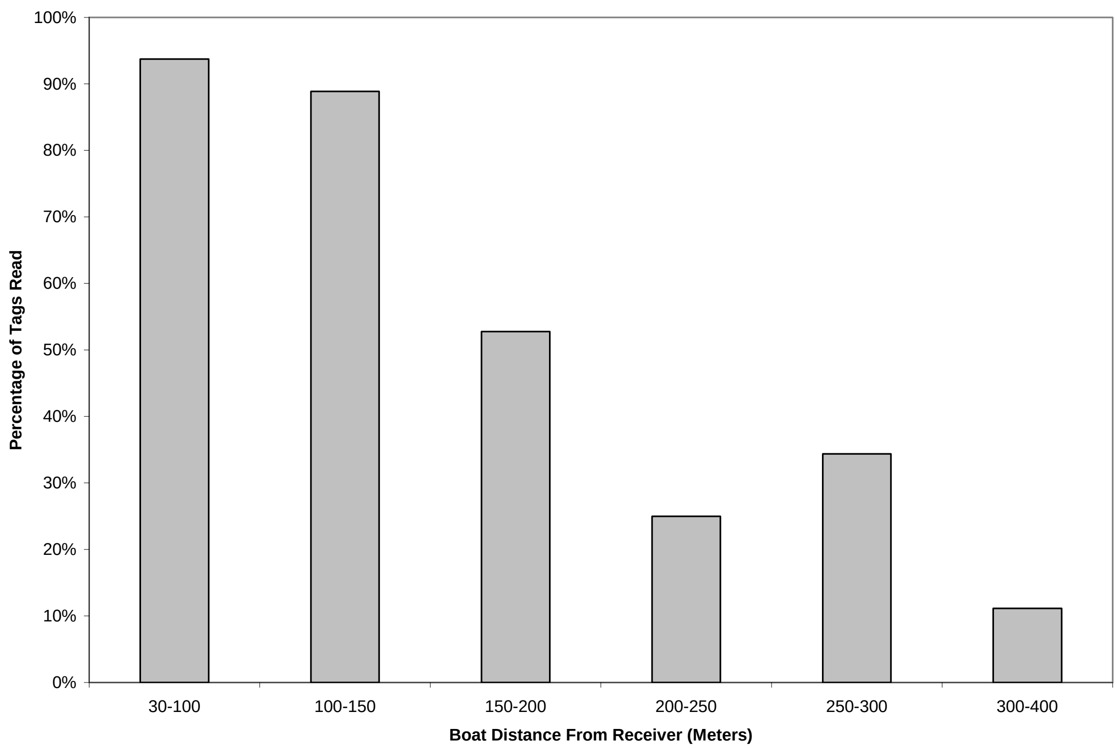

Figure 6. Small vessel read distances (Four highest tags)

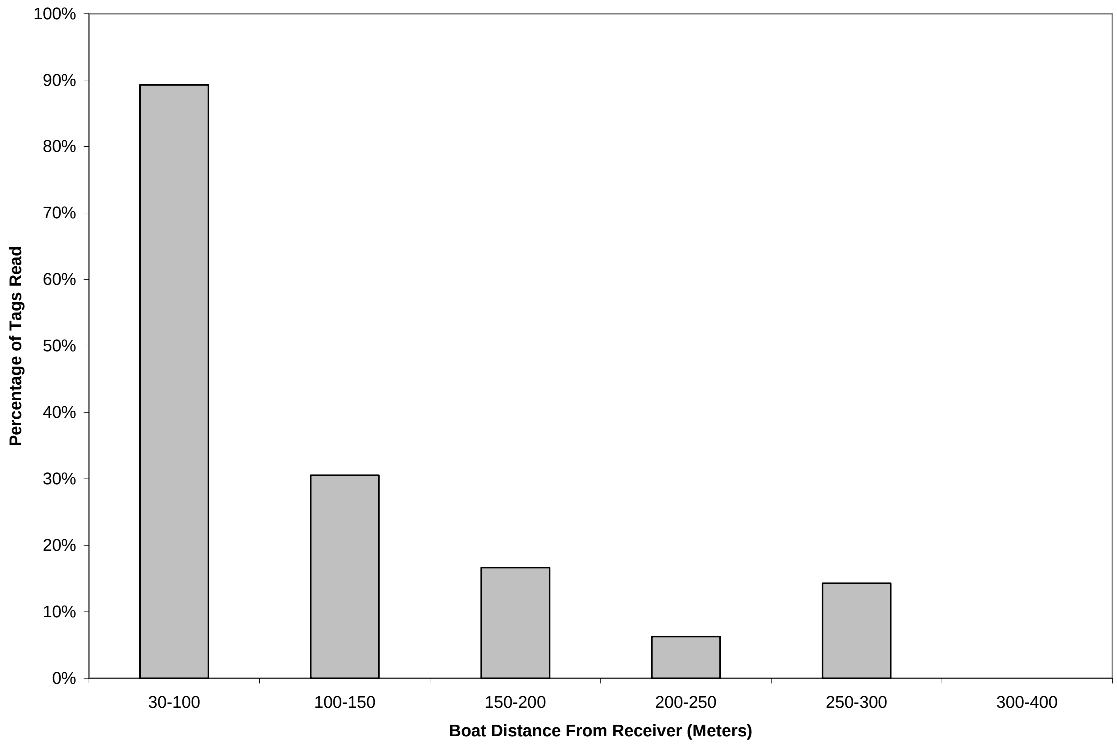

Figure 7. Small vessel read distances (Four lowest tags)

At distances greater than 100 meters, a tag's height had a major impact on its read rate. This can be most easily viewed by comparing the read rates in Figure 6 to those in Figure 5. Between 100 and 150 meters, 89% of the highest tags were read during receiver interrogations, where as only 31% of the lower tags communicated with the reader. At distances greater than 150 meters, the receiver seldom picked up the four lowest tags.

Vessel speed appears to have little if any effect on read rates, as evidenced by a 100% read rate on all 8 tags while the vessel was cruising at 30 knots. Conversely, physical structures appeared to reduce read rates. Tag 8 (see Table 1) positioned inside the center console (and subject to both physical and electrical interferences) achieved a lower read rate (18% of all read attempts) than Tag 7 at a similar height and orientation on the open bow (33%). Horizontal tags also registered higher read rates than vertical tags in each instance where two tags were placed at the same height and location. Where tags were paired, horizontal tags were read on 48% of all attempts (n=147), and vertical tags were read on 34 % of all attempts (n=147).

E. DISCUSSION

This field experiment successfully demonstrated the feasibility of the proposed RFID small vessel monitoring system. Importantly, each reasonably positioned tag on the small vessel was detected during approaches to and departures from the harbor. Even tags placed in unrealistic positions, such as Tag 8 inside the console, reliably communicated with the receiver when the boat entered and exited the harbor. This is important because some small vessels might have rigging above the tag location.

Results on read rates and ranges supplemented the primary purpose of this proof of concept survey. Tags placed at the base of the boat's windshield (1.27 meters above sea level) and higher communicated very consistently with the reader up to 150 meters, and a tag (Tag 1) placed at a still realistic 228.6 centimeters exceeded expectations by consistently communicating to 200 meters. These read ranges illustrate the proposed RFID system's potential to cover waterways as wide as 400 meters with two land-based receivers.

Commercial off-the-shelf (COTS) products were used for the entire proof of concept experiment. This testifies to the flexibility of RFID technology and further indicates the feasibility of a small boat monitoring system. The use of COTS technology would minimize development cost and allow the government-funded project to be tested and fielded much earlier than a system developed in-house. In addition to using entirely COTS products, the RFID monitoring system was easy to set up and use. A consistent small vessel monitoring system was set up at the entrance to Santa Cruz Harbor in less than one hour. Tags were affixed quickly with electrical tape, and a purposeful lack of attention was paid to any possible electrical or physical interference.

Considerably more time and effort would be needed to set up a permanent fixed system, since the receiver was powered by a generator, raised on a portable tripod, and communicated directly with a laptop. A permanent system would need to be fixed securely above the water line[9], connected to power, and linked to the server wirelessly or via cable. The effort required for set up still appears minimal, considering the likelihood that power is likely available at many bottlenecks in waterways and wireless technologies are readily available and decreasing in cost.

Future experiments with the proposed RFID system should compare different active RFID tags to verify that lighter and less complex tags, such as the SaviTag ST-604 have similar read rates and ranges to the SaviTag ST-654 used in the study. The goal should be to minimize the size and weight of tags used on vessels while ensuring maintaining an adequate read range. Experiments should also be conducted with receivers interrogating at a rate that could be used continuously in the field and multiple vessels entering a channel at one time. This type of study could confirm that receivers could process multiple tags at one time, and software could handle multiple reads of each vessel.

Overall, this proof of concept experiment confirmed that a RFID-based system could be used to monitor small vessels. The key advantages of the system include its ability to use only COTS technology, a read rate that covers many bottlenecks in waterways, and simple set up and use that increase the likelihood that the system could be fielded quickly and successfully.

9 Just how high the receiver should be placed could be examined in future trials.

THIS PAGE INTENTIONALLY LEFT BLANK

VIII. GUIDELINES FOR IMPLEMENTING THE PROPOSED RFID SYSTEM

Based on the findings discussed in the previous sections, it seems that an RFID system for monitoring small vessel movement on U.S. waterways may be both feasible and advantageous for several key stakeholder groups. Yet there are many considerations that must be addressed for such a system to be implemented. The guidelines listed below highlight some of these considerations and recommend courses of action that could be taken to implement the proposed RFID monitoring system.

A. PILOT STUDY

Based on the success of the proof of concept study, a pilot study would be an advisable next step. Whereas the proof of concept study was limited in nature and occurred under controlled conditions, a pilot study would test the effectiveness of the RFID system over a longer period of time in a more challenging setting. This would allow stakeholders to better understand the ways in which RFID technology might be most valuable to them. (A pilot study could also be an important tool for determining which agencies should fund the RFID system.)

B. COMMERCIAL OFF-THE-SHELF TECHNOLOGY (COTS)

Further testing of COTS is necessary to determine whether it will be possible to use already existing RFID components in a small vessel monitoring system. A system based on COTS equipment would be easier to implement and more cost effective than a system that required significant new development. Slight changes to COTS equipment could likely be made if needed without adding substantial cost or development effort.

C. MULTIPLE STAKEHOLDER NEEDS

Testing and design efforts should consider the diverse needs of the many potential stakeholders. Homeland and maritime security organizations (including USCG) have already expressed a strong interest in an RFID small vessel monitoring system, and fisheries/resource managers (particularly NMFS) are eager to learn more about how RFID could enhance their programs. Because various stakeholders may benefit from the same small vessel data, it is imperative that the system be attentive to multiple needs from the beginning stages. Further, system developers should recognize that once the system is in place, unanticipated potential uses might be identified. A responsive and flexible system should be able to adapt to new uses.

D. PRIVATE CITIZEN PARTICIPATION

Organizations hoping to implement a small vessel monitoring system should carefully consider how to best to introduce the system to private citizens. First, they should emphasize the benefits the system could provide to boaters (such as enhanced boating safety or simplified and automated registration). They should also consider making boater participation voluntary in the first phase of an RFID monitoring program. Providing incentives (such as reduced registration cost) could encourage boaters to participate. Further, any increased costs associated with the RFID system should not be passed on to private citizens in the early stages of implementation, if possible. Once the system has proven valuable to boaters, their willingness to pay a bit more for boat registration (and their support of the program) may increase.

E. RFID POLICY AND REGULATIONS

Those interested in an RFID system also need to ensure that their system design meets the requirements of applicable federal, state and local policies that govern tracking technologies (such as the E-Government Act of 2002). (U.S. Government Accountability Office, 2005) Because these requirements likely include attention to data collection, storage, access and use, they can assist program developers in designing the most responsible and secure system possible. Issues that developers will want to address include the following:

- What kind of data will the system collect?
- Which organizations will have access to the data?
- How will they handle new organizations that wish to gain access in the future?
- What steps will be taken to secure data and prevent misuse?
- To what extent will data be linked to other government data sources? (Balkovich et al., 2005)

Thorough and open compliance with technology policies and regulations may also increase public comfort with the monitoring system.

With careful attention to these guidelines, maritime security and resource management agencies should be well positioned to implement an RFID small vessel monitoring system in U.S. waterways. More detailed research about the various ways in which specific programs might benefit from an RFID monitoring system could further equip agencies to move forward with the program.

THIS PAGE INTENTIONALLY LEFT BLANK

IX. CONCLUSION

Radio frequency identification is emerging as an increasingly viable tracking and monitoring technology. Monitoring small vessel movement on U.S. waterways is a largely unexplored but potentially valuable RFID application. This thesis aimed to propose an RFID small vessel monitoring system, analyze the benefits and costs to the system's potential stakeholders, and examine the system's technical and financial feasibility. Its intent was also to present guidelines for implementing the proposed system.

The monitoring system would equip small vessels with active RFID tags, and receivers would be placed in bottlenecks and high risk areas. The vessels' tags would be interrogated as they came into contact with a receiver's read field, thereby identifying and recording their presence.

The proposed system of monitoring small vessels with RFID could benefit several key stakeholders, including maritime security agencies, resource managers (such as fisheries and environmental managers), and the public. Maritime security and law enforcement agencies could identify and track unregistered vessels or suspected threats, and RFID data could merge with other intelligence data to create actionable information. Search and rescue agencies could avoid deploying resources unnecessarily by using the RFID system to determine when vessels returned to port. RFID could help resource managers (who currently rely on limited observational and survey data) improve their understanding of human use patterns on waterways. The public could benefit from search and rescue/law enforcement agencies' enhanced ability to perform their duties and more convenient registration processes. Because tags are only detected when within range of RFID receivers, the system would also have a relatively limited impact on citizens' privacy (a major concern regarding any system of monitoring human movement). Protective legislation and thoughtful design would further prevent the RFID system from violating the public's privacy rights.

Because so many groups may benefit from RFID-based small vessel monitoring, it is important to examine who should pay for the system. Stakeholders with relatively large budgets could more easily absorb a failed attempt at improving their programs' performance and therefore might be better suited to fund new technological systems. In this case, maritime security and search and rescue organizations most likely have the greatest budget resources and might be good candidates for funding the monitoring system. A pilot study could help determine which of the many stakeholders would likely receive the most benefit from (and should therefore perhaps initially fund) the RFID system.

A proof of concept study was conducted with off-the-shelf RFID equipment and two small vessels to assess the feasibility of the RFID system. Results indicate that an RFID receiver positioned at 40 feet above sea level can read tags placed in realistic locations on the vessels at a very high read rate. These initial results suggest that implementing an RFID small vessel monitoring system may require minimal technical effort.

The findings of this thesis suggest that an RFID-based monitoring system could work effectively as one layer in a multi-faceted small vessel monitoring program. An RFID monitoring system could help to protect our nation from small vessel threats while balancing our need for privacy, freedom of movement, and economic vitality. It could also assist in preserving our marine resources and in ensuring that U.S. waterways continue to be a rich and viable source of commerce, sustenance and recreation for years to come.

LIST OF REFERENCES

Albrecht, Katherine and Liz McIntyre. 2005. *Spychips: How Major Corporations and Government Plan to Track Your Every Move with RFID.* Nashville, Tennessee: Nelson Current.

American Civil Liberties Union (ACLU). 2006. "Racial Profiling: Old and New." Web site: http://www.aclu.org/racialjustice/racialprofiling/index.html. Accessed May 2007.

American Civil Liberties Union (ACLU). 2004. "Naked Data: How The U.S. Ignored International Concerns and Pushed for Radio Chips In Passports Without Security." An ACLU White Paper. Web site: http://www.aclu.org/privacy/spying/15778res20041126.html#attach. Accessed May 2007.

Baard, Mark. 2004. "Lawmakers Alarmed by RFID Spying." *Wired News* February 26, 2004. Web site: http://www.wired.com/news/privacy/0,1848,62433,00.html. Accessed May 2007.

Balkovich, Edward, Tora K. Bikson and Gordon Bitko. 2005. *9 to 5: Do You Know If Your Boss Knows Where You Are? Case Studies of Radio Frequency Identification Usage in the Workplace*. Santa Monica, California: Rand Corporation.

Chertoff, Michael. 2007. "Remarks by Homeland Security Secretary Michael Chertoff at the Department of Homeland Security National Small Vessel Security Summit." June 19, 2007. Web site: http://www.dhs.gov/xnews/releases/pr_1182343359257.shtm. Accessed August 2007.

Cline, Jay. 2004. "The RFID Privacy Scare Is Overblown." *ComputerWorld.com*. Web site: http://www.computerworld.com/securitytopics/security/story/0,10801,91125,00.html. Accessed May 2007.

Coleman, Felicia C., Will F. Figueira, Jeffrey S. Ueland and Larry B. Crowder. 2004. "The Impact of United States Recreational Fisheries on Marine Fish Populations." *Science* 305(5692):1958-60.

Crossett, Kristen M., Thomas J. Culliton, Peter C. Wiley and Timothy R. Goodspeed. 2004. "Population Trends Along the Coastal United States: 1980-2008." *Coastal Trends Report Series.* National Oceanic and Atmospheric Administration. Web site: http://www.oceanservice.noaa.gov/programs/mb/pdfs/coastal_pop_trends_complete.pdf. Accessed August 2007.

Dew, Nicholas. 2006a. "Cookies for the Real World: Assessing the Potential of RFID for Contractor Monitoring." Journal of Public Procurement, forthcoming.

Dew, Nicholas. 2006b. Personal conversation in reference to ongoing RFID research.

Electronic Privacy Information Center. 2006. "Radio Frequency Identification (RFID) Systems." Web site: http://www.epic.org/privacy/rfid/. Accessed May 2007.

Fisheries and Oceans Canada. 2007. "Alerting, Detection & Response: Dealing with accidents at sea." Web site: http://www.ccg-gcc.gc.ca/sar/docs/ADR_e.htm. Accessed August 2007.

Fox, Richard. 2001. "Someone to watch over us: Back to the panopticon?" *Criminal Justice* 1(3):251-76.

Fusaro, Roberta A., Glen Allmendinger, Lee Tien, Nick Dew and R. Bhaskar. 2004. "None of Our Business?" *Harvard Business Review* 82(12):33-44.

Hildner, Laura. 2006. "Defusing the Threat of RFID: Protecting Consumer Privacy through Technology-Specific Legislation at the State Level." *Harvard Civil Rights-Civil Liberties Law Review* 41(1):133-76.

International Maritime Organization. 2007. *International Convention for the Safety of Life at Sea (SOLAS), 1974.* "The December 2000 Amendments." Web site: http://www.imo.org/Conventions/contents.asp?topic_id=257&doc_id=647. Accessed July 2007.

International Maritime Organization. 2003. "Guidance for Mass Rescue Operations." Web site: http://www.uscg.mil/hq/g-o/g-opr/MassRescueOps/MROguidance_IMO.pdf. Accessed July 2007.

Kitts, Andrew W. and Scott R. Steinback. 1999. "Data Needs for Economic Analysis of Fishery Management Regulations." NOAA Technical Memorandum NMFS-NE-119. Web site: http://www.nefsc.noaa.gov/nefsc/publications/tm/tm119/tm119index.htm. Accessed August 2007.

Knowledge@Wharton. 2005. “Tag Team: Tracking the Patterns of Supermarket Shoppers.” University of Pennsylvania. Web site: http://knowledge.wharton.upenn.edu/article.cfm?articleid=1208&CFID=31935598&CFTOKEN=52867863&jsessionid=a830d83b1f6655766718. Accessed June 2007.

Larson, Jeffrey S., Eric T. Bradlow and Peter S. Fader. 2005. “An Exploratory Look at Supermarket Shopping Paths.” *Knowledge@Wharton*, University of Pennsylvania. Web site: http://knowledge.wharton.upenn.edu/papers/1293.pdf?CFID=31935598&CFTOKEN=52867863&jsessionid=a830d83b1f6655766718. Accessed June 2007.

Lensvelt-Mulders, Gerty J.L.M, Joop. J, Hox and Peter G.M. Van der Heijden. 2005. “How to Improve the Efficiency of Randomised Response Designs.” *Quality and Quantity* 39(3)253-65.

Marlin. 2006. “Study Points Out Problems with MRFSS.” April 5, 2006. Web site: http://www.marlinmag.com/news/news/study-points-out-problems-wint-mrfss-41747.html. Accessed July 2007.

McCullagh, Declan. 2003. “RFID tags: Big Brother in small packages.” *CNET News*. Web site: http://news.com.com/2010-1069-980325.html. Accessed May 2007.

McNeill, Patrick and Steve Chapman. 2005. *Research Methods* Third Edition. New York, New York: Routledge.

National Research Council (Committee on the Review of Recreational Fisheries Survey Methods). 2006. *Review of Recreational Fisheries Survey Methods.* Washington, D.C.: The National Academies Press.

Newmarker, Chris. 2007. “Toll records trip up philanderers.” *ABCNews.com*, August 10, 2007. Web site: http://abcnews.go.com/US/wireStory?id=3467404. Accessed August 2007.

O’Connor, Mary Catherine. 2007. “RFID-Enabled Billboards Talk to Mini Motorists.” *RFID Journal* January 29, 2007. Web site: http://www.rfidjournal.com/article/articleview/3005/. Accessed August 2007.

Office of Boating Safety. 1999. “False Calls in Washington, Oregon Cost Taxpayers.” United States Coast Guard. Web site: http://www.uscgboating.org/articles/boatingview.aspx?id=27. Accessed July 2007.

Privacy Rights Clearinghouse. 2003. "RFID Position Statement of Consumer Privacy and Civil Liberties Organizations." Web site: http://www.privacyrights.org/ar/RFIDposition.htm. Accessed June 2007.

Rasinski, Kenneth A., Gordon B. Willis, Alison K. Baldwin, Wenchi Yeh and Lisa Lee. 1999. "Methods of data collection, perception of risks and losses, and motivation to give truthful answers to sensitive survey questions." *Applied Cognitive Psychology* 13(5):465–84.

Santa Cruz Harbor. 2007. "Harbor User Groups." Web site: http://www.santacruzharbor.org/education/overview.html. Accessed August 2007.

Sarasvathy, Saras D. 2006. "The Affordable Loss Principle." Darden Business Publishing, University of Virginia. Web site: http://www.effectuation.org/ftp/Affordable%20Loss%20Note.pdf. Accessed July 2007.

Savi Technology. 2007a. "SaviTag Fixed Reader SR-650." Web site: http://www.savi.com/products/SaviReader_650.pdf. Accessed August 2007.

Savi Technology. 2007b. "SaviTag ST-654 High Performance Tag." Web site: http://www.savi.com/products/SaviTag_654.pdf. Accessed August 2007.

Spychips.com. 2006. *Spychips.com – How RFID will compromise privacy, security and freedom.* Web site: http://www.spychips.com/index.html. Accessed May 2007.

Swedberg, Claire. 2006. "Argentine Drivers Use Passive Tags to Pay Bridge Tolls." *RFID Journal*. Web site: http://www.rfidjournal.com/article/articleview/2641/1/1/. Accessed August 2007.

United States Coast Guard (USCG). 2007a. "Missions – Ready Today...Preparing for Tomorrow." Web site: http://www.uscg.mil/top/missions. Accessed August 2007.

United States Coast Guard (USCG). 2007b. "Search and Rescue is No Joke." Web site: http://www.uscg.mil/hq/g-o/g-opr/SARfactsInfo/nojoke.htm. Accessed July 2007.

United States Coast Guard (USCG). 2006. "Boating Statistics – 2005." Web site: http://www.uscgboating.org/statistics/Boating_Statistics_2005.pdf. Accessed August 2007.

United States Coast Guard (USCG). 1999. "Boating Statistics – 1999." Web site: http://www.uscgboating.org/statistics/Boating_Statistics_1999.pdf. Accessed June 2007.

United States Code. 2007. "Numbering Undocumented Vessels." Title 46, Chapter 123. Web site: http://uscode.house.gov/download/pls/46C123.txt. Accessed July 2007.

United States Fish and Wildlife Service. 2001. "Number of Anglers and Hunters Remains Steady." August 15, 2001. Web site: http://www.fws.gov/news/newsreleases/R9/A2D9B201-0350-4BD4-A73477A70A25FC69.html?CFID=9790490&CFTOKEN=24225154. Accessed July 2007.

United States Government Accountability Office (GAO). 2005. "Information Security: Radio Frequency Identification Technology in the Federal Government." GAO-05-551. Web site: www.gao.gov/new.items/d05551.pdf. Accessed May 2007.

United States Government Accountability Office (GAO). 2002. "Technology Assessment: Using Biometrics for Border Security." GAO-03-174. Web site: http://www.gao.gov/new.items/d03174.pdf. Accessed July 2007.

Van Voorhees, David, and Elizabeth S. Pritchard. 2003. *Fisheries of the United States 2002*. U.S. Department of Commerce. Web site: http://www.bio.fsu.edu/us_landings/VanVoorhees2002-fus.pdf. Accessed July 2007.

Wessel, Rhea. 2007. "Bermuda's RFID Vehicle Registration System Could Save $2 Million/Year." *RFID Journal* May 18, 2007. Web site: http://www.rfidjournal.com/article/view/3321. Accessed July 2007.

Wyld, David C. 2005. "RFID: The Right Frequency for Government." *E-Government Series.* The IBM Center for the Business of Government. Web site: http://www.businessofgovernment.org/pdfs/WyldReport4.pdf. Accessed June 2007.

THIS PAGE INTENTIONALLY LEFT BLANK

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California

3. Dean Robert N. Beck
   Naval Postgraduate School
   Monterey, California

4. Dr. Nicholas Dew
   Naval Postgraduate School
   Monterey, California

5. Dr. Bill Gates
   Naval Postgraduate School
   Monterey, California

6. Wendy Walsh
   Naval Postgraduate School
   Monterey, California

7. Dr. Churchill Grimes
   Fisheries Ecology Division
   Santa Cruz, California

8. John Compisi
   Savi Technology
   Mountain View, California

9. LT John A. Crofts
   Naval Postgraduate School
   Monterey, California