NPS-AM-09-126

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Aerial Remote Radio Frequency Identification System for Small-vessel Monitoring

28 December 2009

by

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Prepared for: Naval Postgraduate School, Monterey, California 93943

The research presented in this report was supported by the Acquisition Chair of the Graduate School of Business & Public Policy at the Naval Postgraduate School.

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Abstract

This MBA Professional Report proves the feasibility of using aircraft-mounted RFID antennas to detect commercially available Radio Frequency Identification (RFID) tags affixed to small vessels. The project was conducted because monitoring small vessels in US coastal and inland waters is considered a gap in homeland security, as well as problematic for marine resource managers tasked with enforcing sanctuary and fishing regulations. The premises of the project are that 1) RFID tags are less invasive and more cost effective than other current methods of proposed monitoring, 2) airborne platforms can monitor areas of interest faster and more efficiently than surface-based monitoring systems, and 3) small-vessel registration numbers can be electronically associated with the serial number of the affixed RFID tag. The cost of tagging each vessel is low (around $50 per vessel), and the tag number of any vessel could be read remotely from 0.3 to 0.5 nautical miles (nm) away. The agency reading the tag would be able to retrieve the associated vessel registration information from a national database through a back-end data-link system. This system could improve coastal and port security by providing remote monitoring of real-time vessel location information and could enable improvements in resource management methods by enabling correlation of location and identification data for recreational vessels engaged in natural resource use.

Keywords: RFID, Radio Frequency Identification, Airborne, Vessel monitoring

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Acknowledgments

We would first and foremost like to thank Professor Nick Dew for inspiring us to embark upon this project and to create a product with real potential for impact and action. We are also indebted to Professor Bryan Hudgens for his sage advice and guidance.

We owe special gratitude to Bob Veiga, Senior RFID Engineer at Savi Technologies, for his advice and generosity in supplying the needed hardware through our Cooperative Research and Development Agreement. This experiment would not have been possible without his and Savi's support.

We would like to extend our deep appreciation to NOAA Sanctuaries West Coast personnel Matt Pickett and Lorraine Anglin, without whom our feasibility test would have been impossible. We also appreciate the enthusiastic support and capable professionalism of NOAA pilots LCDR Nicole Cabana, LT Jason Mansour, and LTJG John French. The pilots were an excellent local source of expertise and assistance as we collaborated with NOAA AOC Program Officer LCDR Phil Eastman, and AOC Engineer Jim Roles, who worked against the clock to help with hardware installation.

Thanks also goes to Mike Espiritu and Ernest Edwards of Embassy Suites in Seaside, California for letting us use the hotel roof as a test platform. Not only could we perform the experiment from a high vantage point, but we enjoyed an unparalleled view of the Monterey Bay.

LCDR Jason Appler extends a special thanks to Suzy Komarek for having the patience and understanding of a saint, and to Dr. Frank Schwing and the administrative staff of SWFSC ERD for their support.

LTJG Sean Finney: I would like to humbly thank my wife and son, Mary and Aiden, for their infinite patience and unwavering support during the long hours and days forgone together to accomplish this endeavor. I would also like to thank Dr. Churchill Grimes of the NMFS SWFSC Santa Cruz laboratory for his perpetual support in allowing this project to happen and continue.

Major Mike McMellon: I would first like to thank my beautiful wife, Maryann, for her steadfast support, her never-ending encouragement, and her tireless efforts that bind our family so close together. I could not imagine living life without you, and I look forward to sharing more of life's journeys together. I also must thank my daughter, Ashley, and my son, Jacob, for your ability to make every little thing in life a full-time adventure. You make life fun and spontaneous, and I'll always cherish the many times that you have reminded me that I need to slow down and enjoy today. Finally, I acknowledge that I would have nothing at all had it not been given to me by my God, my Savior, Jesus Christ. All things are possible.

About the Authors

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List of Acronyms and Abbreviations

ACAT	Acquisition Category
AIS	Automatic Information System
AoA	Analysis of Alternatives
AOC	Aircraft Operations Center
CBA	Cost-benefit Analysis
CDR	Critical Design Review
COTS	Commercial Off-the-shelf
CRADA	Cooperative Research and Development Agreement
DHS	Department of Homeland Security
DMV	Department of Motor Vehicles
DoD	Department of Defense
DoDI	Department of Defense Instruction
EMF	Electromagnetic Field
ERD	Environmental Research Division
FAA	Federal Aviation Administration
FFP	Firm Fixed-price (Contract Type)
FPI	Fixed-price-incentive (Contract Type)
FRP	Full-rate Production
GPS	Global Positioning System
GPSr	Global Positioning System receiver
KB	Kilobytes
LRIP	Low-rate Initial Procurement

MHz	Megahertz
MOSA	Modular Open Systems Architecture
MRFSS	Marine Recreational Fisheries Statistics Survey
nm	Nautical Miles
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
PDR	Preliminary Design Review
PESHE	Programmatic Environment, Safety and Occupational Health
PII	Personally Identifiable Information
PMO	Program Management Office
PPBES	Planning, Programming, Budgeting & Execution System
R&D	Research & Development
RADAR	Radio Detection And Ranging
RDT&E	Research, Development, Test & Evaluation
RFID	Radio Frequency Identification
RFP	Request for Proposal
SOW	Statement of Work
SWFSC	Southwest Fisheries Science Center
VHF	Very High Frequency

Executive Summary

This project shows the feasibility of detecting commercially available Radio Frequency Identification (RFID) tags on small vessels with aircraft-mounted RFID antennas. The reason for the project is that monitoring small vessels in US coastal and inland waters is currently considered a gap in homeland security as well as problematic for marine resource managers tasked with enforcing sanctuary and fishing regulations.

The main concepts of the project are that 1) RFID tags are less invasive and more cost effective than other methods of proposed monitoring, such as Global Positioning System (GPS) or Automatic Identification System (AIS) monitoring, and that 2) all small vessels be registered to a national database. Their registration numbers would not only be printed on the vessel (as is now the case for those vessels that are registered separately by states or the USCG) but also would be associated with an RFID tag affixed to the vessel. This concept is analogous to an electronic license plate on a motor vehicle.

The cost for tagging is low (around $50 per vessel) and could be incorporated with the registration fee. The benefit is that the tag number of any vessel could be read from within 1/3 of a nautical mile (or farther as technology is refined), and the agency reading the tag would be able to retrieve the associated information from a national database through a back-end, real-time, data-link system. This back-end to tag number requirement preserves the boat-owner's right to privacy. The only information broadcasted by the tag is the tag number, which is useless to unauthorized personnel in the same way that a motor-vehicle license plate number is useless to other drivers on the road.

This system would enable interested agencies, such as the Coast Guard and the National Oceanic and Atmospheric Administration (NOAA), to remotely identify and monitor vessels that are in areas of interest. This could improve coastal and

port security by providing remote detection of real-time information on vessels, and could enable improvements in resource management methods by enabling correlation of location and identification data for recreational vessels engaged in consumptive or non-consumptive resource use.

I. Introduction

This paper presents the findings of a feasibility study on the use of Radio Frequency Identification (RFID) technology onboard an airborne asset for the purpose of remotely identifying small vessels. The study was conducted in order to broaden the concept, as proposed by the literature so far, of how to apply RFID technology to the problem of monitoring small vessels for the purposes of homeland security and marine resource management. This research considers the strengths and weaknesses of an RFID system. Additionally, this study shows RFID to be a cost-effective alternative to more expensive and complex technologies that perform similar functions. Finally, a procurement template and an acquisition plan for implementing aerial RFID as a component of a multi-tiered approach to homeland security and resource management is included to accelerate potential program-management efforts.

A. Background of Coastal Monitoring Requirements

Since terrorist activity within the continental United States began to escalate in the mid 1990s,[1] culminating in the attacks of September 11, 2001, the United States National Security Strategy has identified several weaknesses in our nation's capacity for insuring homeland security (DHS, 2008). Among these weaknesses are the gaps in port security and monitoring of coastal waterways with regard to small vessels (DHS, 2008). One obvious example is that it would be possible to use a small boat, such as that used to successfully drive explosives into the USS Cole, to target sensitive, shore-side facilities such as the United Nations Building on the East River in Manhattan, New York.

[1] Such terrorism can be (and has been) of foreign origin and politically motivated, such as the 1993 World Trade Center bombing conducted by Ramzi Yousef (Wright, 2006), or domestically motivated, such as the 1994 bombing of the New York subway by Edward J. Leary.

The question of how to monitor and account for the movement of small vessels[2] (for the purpose of identifying anomalies that may pose a threat to shore-side or floating targets of interest) has proven to be a difficult one to answer. The small size, ubiquity, and private nature of these vessels make it very difficult to track and account for them, particularly within the current small-vessel regulatory environment. Anyone who has spent time in a busy inland waterway or urban harbor on a weekend in July knows that individual boats can become practically invisible in the glare, the chop, and the confusion of crowded and chaotic movement. Conversely, a recreational-sized boat can also become invisible on the horizon of a large, empty bay or coastal waterway. And for vessels that—despite these physical obstacles—can be identified with current visual methods as vessels potentially needing more attention, there is the issue of accessibility of information. At the time of this writing, federal (Coast Guard) registration is only required on vessels greater than 30 feet in length or displacing[3] five gross tons. All other vessels[4] need only be registered with the state of their home port. The result of this separation is that registration data on small vessels is inconsistent and difficult to access, particularly since a vessel may be operated far from its home port, where local or even federal authorities do not have easy access to information. These difficulties are compounded by the fact that the areas in which boats operate are vast, often adverse, and inherently difficult to patrol.

In such an environment, there are few barriers to entry for an individual. For example, a person needs a government-issued driver's license to drive a car, and each car is driven within the confines of roadways. Cars also have a visible registration number that is accessible nationally and is easy for law enforcement to

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[2] Defined as any watercraft, regardless of the method of propulsion, that is generally less than 300 gross tons and used for recreational or commercial purposes (DHS, 2008).

[3] Displacement refers to the amount of water displaced by the hull of a vessel.

[4] Of the approximately 21 million small vessels in US waters, approximately 8 million, or 38%, are unregistered (Allen, 2008).

see. But anyone can operate a small boat, for which registration information is hard to see and confirm on water. In addition, large waterways require much more manpower to patrol from the surface than would be necessary on roadways. There are approximately 10,758 nautical miles[5] of coastline in the United States ("United States," 2009). The monitoring of waterways, therefore, requires a system that can be used over long ranges and is flexible enough to work in various environments and coastal conditions.

Regardless of the obvious difficulties, as noted during the DHS Small Vessel Summit (DHS, 2008, p. 55), coverage is needed. Specifically, there is a need for a means to identify individual vessels remotely, with access to information about their ownership, their owner's place of residence, their registration status, and their boating record.

Interestingly, marine resource managers share the same problem with access to vessel information and location as the DHS. As pressure on our marine natural resources increases—from sources such as climate change and over-fishing—resource managers are faced with a greater need to monitor human activity around the protected and regulated areas of our coasts. The areas to be monitored are vast[6] and, as with security monitoring, the manpower for patrol is insufficient.

The question of how to account for small vessels, whether for national defense or resource management, has become one of maximizing information and coverage per unit of monitoring effort per dollar spent.

The concept of using RFID technology to monitor small vessels was proposed in 2007 by NOAA Corps Officer LCDR John Crofts while he was a student at the Naval Postgraduate School (Crofts, 2007). Crofts' proposal was to monitor vessel

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[5] The coastline is defined as the land border of an area of water that stretches out 12 nm to the US seaward limits of the US territorial sea, and 200 nm to the limits of the US Exclusive Economic Zone.

[6] The US has approximately 1.8 million square miles of coastline and seaways, not counting the area added by territorial water boundaries (Kinney, 2008).

movement through bottleneck waterways around harbors and urban coastal areas by mounting RFID interrogators at fixed locations on shore, and aiming them at the appropriate angle to read data from tagged vessels passing through the monitored area. This system is premised on the assumption that small-vessel registration become integrated nationally and that all registered vessels be required to display RFID tags.

An RFID monitoring system is also premised on the concept that a negative response is an actionable event, meaning that the interrogators are paired with video or infrared (or other such sensing devices), so that the detection of a vessel correlated with the absence of the detection of a tag raises a red flag. The theory is that an unregistered vessel, for example, passing through the spans of the Highway 80 San Francisco-Oakland Bay Bridge, perhaps having just passed under the Golden Gate from an unknown origin, would sound an alarm to on-watch personnel as being a vessel target with no tag verification. This would be probable cause for brief high-definition surveillance, which might reveal suspicious cues on the vessel—perhaps suspicious weapon-like objects being handled, etc. If alarm and supporting evidence were sufficient, a patrol could be dispatched to intercept the vessel before it traveled the 0.5 nautical miles around the piers off 2nd Street and to within meters of the 30,000 baseball fans at AT&T Park.

The fixed system proposed by Crofts has potential but is limited by the scarcity of areas in which commercially available RFID technology could adequately create such bottleneck monitoring points.

The premise of this paper is the addition of a roving airborne RFID interrogation capacity to the concept of fixed systems, and the integration of both into a multi-tiered surveillance system that serves multiple end-users by selective provision of need-to-know information.[7]

The authors envision a system in which RFID tags are the equivalent of electronic license plates, and are readable from not only fixed bottleneck locations but also from resource-management and DHS aircraft. Tag numbers would be matched against a national database via secure networks, and the information about the tag-holder that would be available to a unit making an inquiry in the database would be limited to the information only that unit is authorized to access. For example, if a National Marine Sanctuaries enforcement officer flew over a sanctuary closed to fishing, saw boats fishing there, and picked up their tag numbers via the aircraft's RFID reader, the information she could access through the database would be limited to name, address and fishing license-type data. However, an FBI agent following a lead on a potential terrorist attack in a harbor may have additional access to the vessel-owner's criminal record, citizenship information, and his/her terrorist watch-list/no-fly status.

Until the research summarized in this paper was conducted, the concept of incorporating RFID tags on surface vessels and interrogating them from aircraft had not been attempted or documented. Additionally, some doubted whether it was even feasible to read a commercially available tag from the distances and angles necessary for airborne interrogation.

B. Strengths and Weaknesses of RFID Monitoring

There are distinct limitations to using RFID for monitoring purposes. However, the primary weakness with RFID can also be considered one of its major strengths, depending on the perspective of the small-vessel issue being considered.

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[7] The concept of fixed RFID monitoring stations was shown to be extremely low cost. While adding an aerial component may add to the cost of an RFID system, the benefits of the system and the monetary costs associated with them, as outlined in this paper, suggest that the resultant capability of the system far outweighs the marginal increase in cost.

From a purely technical and functional point of view, RFID is extremely limited by a short, line-of-sight range of effectiveness and by the nature of the information gained from RFID activity. More specifically, the only information resource-management or DHS personnel will receive via the RFID tag/reader interface is the identification number of a vessel's tag and that will only be received from a tag that is within approximately 0.75 nautical miles of the reader. The implications of these limitations are that a vessel must be intentionally "looked at" in order to receive a tag number and that the information corresponding to the tag number received is limited to the access level of the interrogating agency.

Compared to current suggestions to require all vessels to carry an Automatic Information System (AIS) or even a GPS-linked monitoring device, we consider the limitations of RFID to be an advantage. This is especially true when one considers the constitutional right to privacy of US boat owners, the primary stakeholder in the issue of vessel monitoring. The RFID system proposed by this paper is in the category of "passive" observation, which distinguishes it from systems such as AIS that actively and continually broadcast personally identifiable information (PII) and location data about a vessel and its owner.

Although AIS and GPS are effective monitoring tools and have their place in helping resource and security managers monitor commercial vessels, they are costly to implement and maintain, likely to be considered invasive by the public, and overwhelmingly cumbersome to use on small vessels, given the current state of technology. For example, AIS is currently required of many commercial vessels, with the result that large ships and boats working in and around vessel traffic schemes show up on all compatible RADAR and electronic navigation displays as special icons with directional vectors and data summaries. AIS broadcasters alone can cost hundreds to thousands of dollars, but beyond that, they require integration with professional-grade bridge equipment that adds thousands more to the cost per boat. How can one realistically expect the taxpayer, let alone a citizen who owns a 17-foot runabout that may have cost less than an AIS broadcaster, to pay for such systems? This is a case in which the law of diminishing returns may apply. Added to the financial limitations of AIS is the fact that even now, with only commercial vessels carrying AIS, professional mariners operating in the vicinity of a busy port with many other commercial vessels will see an overwhelming amount of AIS information on their navigation systems, making it difficult to distinguish between significant and insignificant information on the displays. If small vessels were broadcasting AIS as well, the amount of traffic around commercial ports like Long Beach, Galveston, Boston, Baltimore, Philadelphia, New York, and many others would likely create AIS information overload for all users.

RFID is a much more manageable, affordable, and palatable means of identification because it is a focused and short-range monitoring tool used at purposeful locations, and RFID tags carry only an RFID number that is meaningless until correlated via a secure network with a national database of information. Thus, RFID would be a more appropriate way of addressing whether further investigation is necessary. In the event that further investigation is deemed necessary in any individual case, the DHS has much more powerful surveillance tools than AIS and GPS for surveillance.

This paper not only supports the feasibility of using RFID technology from aircraft but also presents a sample acquisition strategy (in Appendix A) for procuring an aerial, RFID small-vessel monitoring system, which supports the claim that RFID is potentially an extremely cost-effective component of coastal homeland security and resource-management strategies.

C. Overview of RFID Technology

Radio Frequency Identification refers to the use of small transponders (called tags) to broadcast coded identification data (such as data normally found on product barcodes) as radio waves to remote receivers. The tags are actually small computer chips custom fitted with an antenna to enable them to transmit data. There have been two generations (Gen) of these chips: Gen 1 chips are coded with a single string of characters. Gen 2 chips separate the tag data into three parts: the tag's purpose (i.e., travel document), the type of tag (i.e., the issuer, such as Wal-Mart), and the unique code assigned to the tag that is matched to information (Manaher, 2008). Tags can be read-only, meaning their code can only be read, or they can be read/write, allowing a program-capable receiver to alter their code.

The receivers typically interrogate the tags by sending a radio signal that initiates an automatic radio transmission of the tag's data. Once received, the interrogators translate the coded data into useable information.

The modern RFID label typically refers to a three-part system, consisting of the tags, the interrogators, and a "back end system" (Manaher, 2008), or mechanism for converting the translated tag data received by the interrogator into actionable information. This method, the third part of an RFID system, is usually a computer system that matches the tag ID to its corresponding information in a database. For example, RFID systems used to prevent loss or theft of pets[8] consist of a small chip,[9] the size of a grain of rice, encased in bio-safe material and encoded with a number that identifies the chip. The Gen 2 chip identification code includes digits that identify which pet-monitoring company owns the chip. This chip is injected under the pet's skin on the back of its neck.

When a stray animal is brought to a veterinarian or SPCA[10] shelter, the veterinarian or shelter personnel scans the animal with a hand-held interrogator that broadcasts a radio signal. If present, a coiled antenna in the tag will be activated by this signal and reflect its ID back to the interrogator.

Once received, the ID is translated by the interrogator and then transmitted to a computer, either by data cable or wirelessly. The computer then accesses the

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8 Pet tags are commonly referred to as "microchips."

9 The term "chip" is used interchangeably with "tag," as an RFID tag is a modified computer nanochip.

10 SPCA is the acronym for the Society for the Prevention of Cruelty to Animals.

database of the appropriate monitoring company via a "middleware" (Rieback, Crispo & Tanenbaum, 2006) program using a secure website, in which the tag ID is matched to archived information about the animal—specifically the name, address and contact information of the animal's owner. Using this analogy, our concept is, essentially, to "chip" small vessels with systems powerful enough to be read from a plane.

1. History of RFID

The roots of RFID can be traced back to World War II and the advent of radio detection and ranging (RADAR) (Crofts, 2007). It was soon discovered that if German planes could roll their aircraft while approaching their base, then it would change the radio signal reflected back. This would allow German RADAR operators the ability to distinguish between "friend" and "foe" (Jones & Chung, 2008). Later in the war, the British were able to construct the first passive RFID system by affixing a transponder on their planes that would emit a signal when interrogated by Allied RADAR. It was not until the 1970s, however, when the RFID chip as we know it was developed that could contain fixed information in a "programmable-read-only-memory" (PROM) (Ranky, 2006; Technovelgy, 2006).

2. Passive RFID

The basis of this style of tag, as the name suggests, is to remain inactive until activated by a reader (Savi Technologies, 2007). The tag itself is not powered through an auxiliary power source, e.g., a battery (Savi Technoligies, 2007; Technovelgy, 2006). Instead, this style of tag is powered through a coiled antenna that creates a magnetic field when interrogated by a reader, thereby drawing power from the reader (Technovelgy, 2006). This method of powering the chip has several advantages and disadvantages.

Fundamental disadvantages for passive RFID tags come in the form of power, lifecycle, read-rates and read-rate distances (Li, Visich, Khumawala & Zhang, 2006; Savi Technologies, 2007). Since these passive tags receive power from an outside source via radio frequency from the reader, the tags do not function without the outside power source (Jones & Chung, 2008). It is difficult, if not impossible, to integrate the tag into a standalone sensor package; such a change would require a second interface to tie them together (Savi Technologies, 2007; Technovelgy, 2006). By not having their own power source, passive RFID tags can have an extended lifecycle that can be unnecessary when the item no longer needs to be tracked, such as when it is purchased, removed from service or destroyed (Technovelgy, 2006). Lastly, the passive RFID tag has much lower read-rate distance ability because it lacks a stand-alone power source (Savi Technologies, 2007). The RFID tag must be within close proximity to the reader in order to have an appropriate signal strength to be read (Technovelgy, 2006; Lee & Kim, 2006). This can lead to the inability to read tags sufficiently in a hurried environment.

There are, however, several key advantages to this type of tag. Since the tags do not require an auxiliary power source, the lifespan of the tags can reach up to 20 years (Jones & Chung, 2008). They are considerably less expensive to construct[11] (Technovelgy, 2006), and because of their independence from a power source, their size is also considerably smaller,[12] allowing them to be used in a wide variety of applications (2006).

3. Active RFID

Active RFID tags have a power source, providing them the capability to constantly transmit information (Savi Technologies, 2007; Lin, 2008). The power source may be an internal battery that may or may not be serviceable by the end-user, or it maybe an external battery that is powering other sensors as well (Savi Technologies, 2007; Jones & Chung, 2008). As with passive tags, active RFID tags have both distinct advantages and disadvantages.

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[11] The cost of a passive tag can be reduced to 40 cents.

[12] Passive RFID tags can be “shrunk” to almost the size of a grain of rice.

Some of the distinct disadvantages associated with active RFID tags are size, power consumption, cost, and maintainability (Savi Technologies, 2007; Technovelgy, 2006). Because the active tag requires an energy source, the tag is usually much larger in size. This may limit the tag's potential uses in some applications (Savi Technologies, 2007). In an environment in which space can be at a premium, this attribute can have serious shortcomings[13] (Technovelgy, 2006). If size is sacrificed for battery performance, there is a high risk that the power source will fail, which can lead to expensive errors in tracking[14] (Savi Technologies, 2007; Li et al., 2006). Service-life cost can be a drawback if the tags are to be used over a period of time that would require the necessity of trained personnel to perform periodic maintenance of the unit and its power source (Jones & Chung, 2008; Borthick, Bowen & Gerard, 2008). Lastly, the cost of purchasing an active tag can be fifty times larger than a passive tag (Technovelgy, 2006).

Conversely, there are many distinct advantages of having an active RFID tag. Because the tag has its own power source, the tag can have considerable signal strength, enabling transmissions up to hundreds of meters (Crofts, 2007; Savi Technologies, 2007; Technovelgy, 2006). The read-rate capability is not limited to the tag;[15] rather, it is limited to the reader and how fast it can capture the tag data (Savi Technologies, 2007). That data can contain diagnostic information, can allow the tag to be integrated into a sensor array that can be networked to allow for real-time tracking, and can be used as a continuously monitoring security system (Technovelgy, 2006).

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[13] Imagine a palette full of products that need to be tracked individually. Adding an RFID tracker the size of a pack of gum can limit the space to place product considerably.

[14] Imagine if that same palette mentioned above had 1/3 of its tags disabled due to dead batteries.

[15] Multi-read-rates are one of the most desired advantages.

4. Privacy Issues with RFID

As with other recent advances in information technology—such as the growing ubiquity of internet use for everything from academic research to buying shoes—the rapid development and implementation of RFID technology has created a unique set of issues with regard to privacy.

> The right to privacy encompasses a wide variety of concepts. Perhaps the most famous definition of privacy was […] the "right to be left alone," by Justice Louis D. Brandeis in Olmstead v. United States, 277 US 438[1]. In the digital era, informational privacy is a focus of increasing public concern. Informational privacy refers to the right of an individual to retain control over the collection and use of personally identifiable facts and information about their daily lives. (Kelly & Erikson, 2005)

Before the use of a computer to manage information, it was much easier to control the collection and use of PII. There was more of a physical barrier to cross since information could only be collected in person and could only be stored on printed media that was kept in restricted locations (Kelly & Erikson, 2005).

Even public information, such as property title information, was difficult to access. But today, with the majority of public and private information being handled by databases accessible through the internet (Brown & Kros, 2003), PII is more accessible than ever.

This problem will exist with or without RFID technology, but RFID does increase the ease of access to PII by making information that was previously available only through some form of direct contact now available by remote sensing.

It is important to note, however, that within the typical RFID system, the critical information—for example, residential or financial information, technical information, etc.—is not stored on the tag itself and, therefore, is impossible to be transmitted by the tag. The only thing stored and transmitted by the tag is the ID number of the tag. This number must be matched to the desired information by the back-end system. Therefore, the security of PII is dependent on the security of the database, not the RFID tag, just as the security of a car owner's PII is dependent on how well the database is secured at the Department of Motor Vehicles (DMV), not whether people can see the license plate number.

This need for association, although reassuring in the respect that PII cannot be retrieved from a tag without access to its corresponding database, does not eliminate privacy concerns. In fact, not only does RFID still have the potential to compromise static PII (see Chapter I.C.5 titled RFID Susceptibility to Hacking) but also it introduces new concerns unique to RFID (Kelly & Erikson, 2005). For example, Lee and Kim (2006) summarized RFID privacy threats as falling into four major categories: location, constellation, preference, and transaction threats.

Location Threat: Regardless of whether the information associated with a card is accessible, tag readers are inconspicuous and can be placed or used by unauthorized entities without the owner's knowledge or consent. This reveals at least the location of a tag and makes that location subject to unauthorized disclosure.

> What if a still-enabled chip was the basis for a burglary? Tech Savvy burglars could purchase readers and drive through neighborhoods on the days that trash or recyclables are collected looking for discarded packaging with embedded tags that indicate expensive computers, electronics, cameras, etc., were purchased. If the RFID tag is embedded into the product itself, a thief could simply walk or drive by a house and note the Sony plasma television, Dell computer or other expensive equipment that resided inside. (Kelly & Erikson, 2005)

Constellation Threat: Location threats are more of a problem when considered in light of the fact that particular tag IDs, though not conveying PII, can be learned to be associated with a particular person, forming what is called a "constellation" of tags that are known to be owned by the person.[16] Once a

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[16] The concept of constellations are analogous to the aggregation of various unclassified pieces of information, which when combined create a potentially classified composite picture and an Operations Security (OPSEC) breach.

constellation is established—for example, if someone were being followed and the follower learned the ID of merchandise tags active in the person's coat, hat, mobile phone, and wallet—various readers could be used to reveal the location of that person's objects.

This is a significant problem when considered in light of future technological advancements to place RFID reading capabilities on mobile phones, which will be widely available to the public (Lee & Kim, 2006). It is not difficult to imagine good hackers modifying RFID-enabled phones, giving them the capability to track constellations.

Transaction Threat: The ability to infer transactions between people when tags move from one constellation to another.

Preference Threat: The notion that some seemingly innocuous information, such as manufacturer and product type, may be part of a tag ID and can reveal information about a person's preferences.

5. RFID Susceptibility to Hacking

As shown by Rieback, Crispo, and Tanenbaum (2006), because of the RFID tag's simplicity and the general lack of attention paid to securing the interface between RFID tags and their middleware, the tags themselves can be re-programmed by Radio Frequency (RF) to insert malware into back end-system programs when scanned. This malware could be used to initiate malicious virus or worm activities such as Denial of Service (DoS) attacks (in which system function is inhibited) or could even compromise the security of a back-end database, making it possible for hackers to access information via openings created by code inserted with RFID data.

Safeguards against these types of attack would be fairly simple to incorporate into RFID systems, but they have not yet gained support from industry.

D. Potential for RFID Monitoring of Small Vessels

As outlined in this paper, there is a need to monitor small vessels for the purposes of port security, law enforcement, and marine resource management. Indeed, Crofts (2007) also noted a need to improve search and rescue (SAR) capacity in the marine environment via RFID capabilities.

It is well known that more advanced systems of vessel monitoring exist and are in place for large vessels.[17] The International Maritime Organization's (IMO) *International Convention for the Safety of Life at Sea* (SOLAS) 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. (IMO, 2007)

AIS is a system that integrates location, speed, course, and qualitative information from an array of electronic sources on the ship—including the navigation software and the ship's computerized RADAR system—then broadcasts the information by VHF radio to all other ships and land stations equipped with receivers (USCG, 2009). As mentioned above, AIS equipment is extremely expensive to purchase and maintain, relies on technology that is not available on the average small vessel, and is considerably more invasive of the boater's privacy than RFID. It is, therefore, not a practical solution to the problem of small-vessel monitoring.

Crofts (2007) points out that although AIS is not required of small vessels, there are other identification requirements they must comply with. As previously mentioned, all vessels over 30 feet in length or over five gross tons in displacement must be documented with the US Coast Guard and are then referred to as documented vessels. All undocumented vessels with propulsion machinery must be

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[17] Vessels over 300 gross tons.

registered by name of vessel and hailing port[18] with the state in which the hailing port is located (*USC*, 2007).

Currently, the only way to identify the 13.2 million small vessels in the United States (DHS, 2008) is to get close enough to physically see the registration number or name and port of the vessel (Crofts, 2007). An RFID system could be used to make this information available by remote sensing, enabling management agencies to identify and monitor movement of a large numbers of vessels from a great distance at a relatively low cost.

Crofts' (2007) proposed and field-tested RFID experiment consisted of a customized RFID system using active RFID tags encoded with unique identifiers that would correspond to vessel and owner information stored on secure back-end servers. As mentioned earlier, it would not be possible to cover all of the potential roaming area of small vessels. Thus,

> 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. (Crofts, 2007, p. 7)

Active tags were chosen because of the increased distance from which an active tag can be read,[19] allowing for the potential to approach a 100% read-rate. Using a receiver on each side of a "bottleneck" waterway, the system would be capable of monitoring a waterway as wide as 400 meters (2007).

E. Issues That Necessitate Small-Vessel Monitoring

1. Homeland Security, Safety, and Enforcement Issues

[18] "Hailing port" refers to the homeport of the vessel.

[19] The active tags used in the feasibility study had a broadcast range in excess of 200 meters.

a. Port Security

Prior to the plane-based terrorist attacks made against the United States on September 11, 2001, port security was mainly focused on large ships. Since 9/11, the US Department of Homeland Security (DHS), which draws its authority from the *Homeland Security Act of 2002*, has identified small vessels as having considerable potential for use by terrorists acting against the United States. Small vessels are a relatively easy means by which terrorists can deliver weapons of mass destruction (WMDs) and have already been used overseas to deliver Waterborne Improvised Explosive Devices (WBIEDs) (DHS, 2008). At the National Small Vessel Security Summit on June 19, 2007, DHS Secretary Michael Chertoff said,

> I will guarantee you one thing—the enemy is not wasting time. […] Remind yourself about The Sullivans. Remind yourself about the Cole. Remind yourself about that French tanker, the Limburg. This attack technique […] is one they have used before. It is one that they will likely use again. Let us work together to make our protections against this as robust as they can be in a way that preserves the traditional freedom of the seas, our economic mobility and our continued pleasure and boating on our oceans and in our waterways. (DHS, 2008, p. 31)

According to the recently released 2008 DHS *Small Vessel Security Strategy*, there is a need to "enhance maritime security and safety," incorporate the small vessel community as a partner, work to "enhance maritime domain awareness," and "leverage technology to enhance the ability to detect, infer intent, and when necessary, interdict small vessels that pose a threat" (2008, p. iv). The strategy makes an impressive case for the need to consider small vessels and outlines an exhaustive list of regulatory documents that must be considered in the strategy.[20]

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[20] Regulatory documents include, but are not limited to, *National Strategy for Homeland Security and the DHS Strategic plan*, *National Security Presidential Directive-41*/*Homeland Security Presidential directive-13 (NSPD-41/HSPD-13)*, *National Plan to Achieve Maritime Domain Awareness*, *Global Maritime Intelligence Integration Plan*, *Maritime Operational Threat Response Plan*, *International Outreach and Coordination Strategy*, and Maritime Transportation System Security Recommendations.

It is interesting to note that in the development of all of these strategies and regulations, the DHS has seemingly remained conscientious of the need to preserve the privacy and rights of small-vessel operators. This is partly due to the constitutional responsibility the Federal Government has to its citizens, but it is also due in part to a component of ingratiation since the plan recognizes the need for cooperation from small-vessel operators as "eyes on the water" watchdogs. Particularly with regard to the use of technology to address small-vessel management, the 2008 DHS report states, "Technology will serve as an important, complementary component to enhance subsequent plans, initiatives, and actions […] but it is not the sole answer to ensure small vessel security. Additionally, leveraging technology will mitigate risks but should also minimize impacts to small vessel operators" (2008, p. 15). It is precisely this need to balance a requirement for maximum information with a necessity for minimum impact on small-vessel operators that may prove RFID—with its low cost, low maintenance, and limited tracking ability—to be an ideal technological application for the purpose of monitoring small vessels.

In June of 2008, the DHS convened a summit with representatives from various government agencies and private and commercial boating communities to develop recommendations for recreational boat security. RFID was suggested at this summit as a means for monitoring small vessels (Brownstein, 2008; Lipowicz, 2008).

b. Safety and Enforcement

As noted by Crofts (2007), one of the primary challenges of maritime search-and-rescue organizations, such as the United States Coast Guard (USCG), is discerning between real and false alarms. A search-and-rescue effort at sea requires an immense amount of resources. Crofts estimated the cost of a rescue effort at a minimum of $3,700 per hour.[21] At this rate, false alarms are an enormous

[21] $3,700 an hour for each aircraft, $1,550 an hour for each cutter, and $300–400 an hour for small boats (USCG, n.d.).

cost to the taxpayer, estimated to be approximately $74 million annually nationwide.[22] A significant percentage of these false alarms are due to calls from concerned family members or inaccurate overdue reports. An RFID system could easily be used to verify the location or return of vessels suspected of being missing. In the event that a vessel were truly missing, RFID monitoring could provide information that would help the USCG more accurately pinpoint where the vessel might be found.

In addition to search and rescue, the USCG, the National Oceanic and Atmospheric Administration (NOAA), and various state and local agencies are concerned with illegal boating activities, such as smuggling of drugs or illegal immigration and illegal fishing. RFID could be useful to these agencies by enabling them to monitor vessels passing through bottleneck surveillance areas and/or by detecting them during active search missions.

F. Marine Ecosystem Management Issues

Of the issues that necessitate small-vessel monitoring, resource management is perhaps the most complicated to communicate. Over the next several sections, we will attempt to outline the major components of US marine resource management. The goal is to familiarize the reader with the complexity of the resource-management environment and accentuate how convoluted the management framework has become. The relevance of this discussion to RFID is that we believe RFID tagging and universal registration of vessels would offer resource managers a way of improving the information available for resource decision-makers.

Within the United States, there are currently only two federal agencies that are tasked with managing the marine ecosystem: the National Oceanic and

[22] This estimate was derived by extrapolation of data from the state of Washington, which was the only state with available figures. It is a rough estimate only.

Atmospheric Administration (NOAA) and the United States Fish and Wildlife Service (USFWS).[23] Both of these agencies have multiple offices and laboratories throughout the country that allow them to operate in all of the coastal states. There are two important pieces of legislation that mandate NOAA and USFWS to conduct marine resource management: the 1976 *Magnuson-Stevens*[24] *Fishery Conservation and Management Act*[25] *(FCMA* or *Magnuson-Stevens Act)* (US DoC–NOAA, 2007b; Hsu & Wilen, 1997; NRC, 2006), and the 1996 *Sustainable Fisheries Act (SFA)*[26] (US DoC–NOAA, 2007b; Hsu & Wilen, 1997; NRC, 2006).

1. Background of Marine Ecosystem Management Legislation

The *FCMA* was the original piece of legislation that created the architecture for the current policies in the execution of marine ecosystem management (US DoC–NOAA, 2007a). The management was required because policy-makers noted that most of the world's important and valuable fisheries lay in close proximity to the continental shelf[27] (USCG, 2008b), and steps were needed to secure the economic prosperity of the marine fishery in the United States. It should be noted, however, that because of the highly migratory nature of many of the ocean's species, this policy did very little to secure the United States' fisheries (Hsu & Wilen, 1997). It was not until the 1982 United Nations Law of the Sea Convention,[28]—in which the boundary known as the Exclusive Economic Zone (EEZ) was extended out to 200

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[23] NOAA, a bureau within the Department of Commerce, will routinely create marine ecosystem policy, and USFWS, a bureau within the Department of the Interior, will enforce those policies, while both agencies coordinate with research and law enforcement.

[24] The *FMCA* was created by Senators Warren G. Magnuson from Washington state and Ted Stevens from Alaska.

[25] The *Magnuson-Stevens Act* was reauthorized by President George W. Bush. This allowed for several amendments to be created to increase rigorous enforcement of the act.

[26] The *SFA* is considered a supplement to the *FCMA* by removing some ambiguity in definitions, setting new standards for by-catch and stiffer consequences for derelict fishing gear.

[27] The continental shelf can extend only a few miles on the Pacific Coast but may extend for many miles on the Atlantic Coast. Therefore, a "line" was drawn on charts to sector off a 12-mile radius from the US Coast as sovereign US territory.

[28] Article 57 of the United Nations Convention on the Law of the Sea (1982).

nautical miles—that the United States (and other nations in their respective territories) were able to legally exclude foreign fishing-vessel fleets from territorial waters as well as curtail domestic fishing fleets (UN, 1982).

In 1996, an amendment was passed, the *Sustainable Fisheries Act* (*SFA*), that helped close several loop holes in the original legislation (Hsu & Wilen, 1997; US DoC–NOAA, 2007a). The following is an example of some of the potentially vague language contained in the original bill: "to provide for the preparation and implementation, in accordance with the national standards, of fishery management plans which will achieve and maintain, on a continuing basis, the optimum yield from each fishery by the United States fishing industry" (US DoC, 2007b, p. 3).

While on the surface this language seems to put forth a clear set of directives, the term "optimal yield" (US DoC–NOAA, 2007a) was only given a definition as "the amount of fish which will provide the greatest overall benefit to the Nation" (Hsu & Wilen, 1997, p. 802). Once the *SFA* was passed, the vague term of "optimal yield" was replaced with "maximum sustainable yield *as modified* by any relevant economic, social, or ecological factor" (US DoC–NOAA, 2007b). Changing the term in this way enabled clarification of which species could be harvested and in what amounts. This action also helped to reduce the amount of by-catch[29] affecting other fisheries that was happening as result of shortened seasons[30] (Hanna, 1998).

[29] By-catch can be defined as the process of catching unintended species while engaged in consumptive fishing. The net result once the unintended species has been procured is that it will die or be killed and discarded. For instance, when fishing for tuna on a large scale, commercial fishermen sometimes catch dolphins in the nets.

[30] Fishery councils have the ability to open and close fishing seasons and to determine the length of the season. Some fishing seasons may last several weeks while others last only mere hours. Because some seasons may be so short, there is a rush to the fishing grounds that creates undesired consequences (e.g., since the season is so short, commercial fishers invest in equipment that will yield them as much as possible in the shortest amount of time).

2. Marine Ecosystem Use

There are two factions within the marine ecosystem framework that are of concern to those who are tasked with resource management: consumptive and non-consumptive actions (Fall et al., 2001). The former can be further defined as an individual or entities engaged in the complete or partial removal of living species from the benthic[31] or pelagic[32] (marine) domain, e.g., commercial fishermen (Mullon, Freon, & Curry, 2005; USCG, 2008b). Non-consumptive marine use can be further segmented into two major categories: recreational and commercial (Vaccaro & Sepez, 2003). Recreational can also be defined as an individual or entity who does not actively remove anything from the marine domain, e.g., whale watching (Beeh, 1999).

a. Consumptive Recreational Use

It was often thought that recreational fishermen had a marginal impact on fish stocks when compared to the large fishing fleets that dotted the US coastlines (NRC, 2006; King, 1995). However, this mindset is proving to be incorrect. According to a 2006 report to Congress by the National Research Council (NRC),[33] there are 14 million recreational fishermen in the US that made almost 82 million fishing trips in the calendar year 2004 (NRC, 2006). According to the NRC, while the impact of each individual fisherman is only a small number of landings, the summation of these landings throughout the country can be quite large. So large, in fact, that some estimates place the landings in excess of what the large commercial fishing fleets can land (NMFS–FSD, 2004). For instance, a study prepared by the National Marine Fisheries Service (NMFS) estimates that in 2005, 11,900 metric tons of the Atlantic Striped Bass were landed by recreational fishermen—as opposed to 3,000

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[31] Benthic means having to do with the ocean floor.

[32] Pelagic means having to do with the open ocean, i.e., the water column.

[33] The NRC is a non-profit institution that has been given a presidential charter to give independent reviews to Congress on science, medical and engineering topics.

metric tons landed by the commercial industry (Shepherd, 2006). That translates to almost 80% of the catch being made by a segment of the consumptive-use population that was thought to be marginal (Shepherd, 2006; NRC, 2006).

The impact made by recreational fishermen is clearly not trivial. The NMFS has also stated that saltwater fishing is a tremendous cost driver within the US economy that generates roughly $82.3 billion annually and supports over 534,000 jobs throughout the country (US DoC–NOAA-Fisheries, 2008, p. 21). With all that recreational fishermen provide to the economy, it would not be that difficult to understand why these stakeholders would have such reservations about any type of fishery resource management that would have a negative impact on them.

b. Recreational Fisherman Rebuttal

Recreational fishermen believe that any type of interference can be construed as unconstitutional, a risk to tourism dollars, an injustice to those who solely rely on subsistence fishing, or just mismanagement of marine resources (Bailey, 2006; Vaccaro & Sepez, 2003). In many state constitutions, it is deemed a right to be able to fish. For instance, Article I, section 17 of the *Rhode Island Constitution* states, "The people shall continue to enjoy and freely exercise all the rights of the fishery and the privileges of the shore" (Conley & Flanders, 2007, p. 93). The *Minnesota State Constitution* states, "Hunting and fishing and the taking of game and fish are a valued part of our heritage that shall be forever preserved for the people" (Morrison, 2002, p. 299). Therefore, many recreational fishermen view this as a right that has been bestowed upon them to give them free and open access to fishing grounds; thus, no regulatory body should stop them.

Some recreational fishermen are concerned that heavily regulating recreational fishing will adversely affect tourism. While there have not been any direct studies to bolster such a claim, there are clear examples of what recreational fishing contributes to a coastal state's income revenues. For instance, California receives almost “two billion dollars annually from recreational fishing activities” (William, 2008, p. 1), and significant portions of those fishermen are tourists[34] (2008, p. 1).

The impact may not only be felt in terms of dollars; rather, the effect may be felt in terms of survival, i.e., subsistence fishermen (Fall et al., 2001). There are several locations throughout this country in which local inhabitants who abide by customs and traditions (Native American tribes) routinely rely on subsistence practices as a primary means of feeding their family (Fall et al., 2001; Vaccaro & Sepez, 2003). According to a report by the National Oceanic and Atmospheric Administration (NOAA),[35] in 1980[36] in the state of Alaska, which had a population level of 640,000 residents, 17.2% of the population directly participated in subsistence activities[37] (Fall et al., 2001). In 2001, of those that participated in subsistence activities in Alaska, 60% of what they harvested was fish (Fall et al., 2001). Thus, it is clear that even a small impact on fishing regulations could have a large impact on subsistence fishermen who rely on this activity as a primary means of survival. It has been purported that a potential reason for fishery stocks declining in the US is not from the amount of fish being harvested from the ocean. Rather, the decline is from poor or faulty management by regulatory officials that may or may not be influenced by inaccurate data (Fish Net USA, 2006; Bailey, 2006). The standard set of data that is routinely scrutinized by individuals at all levels is the Marine

[34] The term tourist is used to signify someone from outside the local area and need not refer to someone from outside the state. California natives are considered tourists if they travel from areas that are inland in the state to coastal areas to fish.

[35] The NOAA is an agency within the Department of Commerce.

[36] 1980 was a baseline year for subsistence surveys in Alaska, and subsequent surveys focus more on regionality and specific species.

[37] The same report also estimates that the effects of the subsistence activities extend beyond the locality for which they were conducted through sharing and social networks.

Recreational Fisheries Statistical Survey (MRFSS)[38] and its subsequent inputs, e.g., aggregate catch per unit effort (CPUE) (NRC, 2006; Pierce & Hughes, 1979).

- (1) MRFSS. The MRFSS is the framework that marine ecosystem resource managers utilize when setting catch quotas and determining fishery season lengths. Its potential inaccuracy is the crux for arguments that are made to denigrate its ability39 (NRC, 2006; Pierce & Hughes, 1979). In 2006, the NOAA asked the National Research Council (NRC) to evaluate the MRFSS and its effectiveness and make potential recommendations of its usefulness and timeliness.40 Subsequently, the NRC submitted their report to the NOAA and Congress outlining the survey's deficiencies.41

- (2) The MRFSS Survey. As mentioned at the beginning of the Marine Ecosystem Management section, of the issues that necessitate small-vessel monitoring, resource management is perhaps the most complex, and the relevance to RFID is that we believe RFID tagging and universal registration of vessels would offer resource managers a way of improving the information available for resource decision-makers. This section on the MRFSS survey accentuates the need for improvement in data-gathering methods for recreational catch.

- The survey is conducted in two ways: point-access or telephone-access (NRC, 2006). For point-access surveys, a surveyor will physically meet vessels or people and ask them questions about their recent fishing experience (NRC, 2006; Kleiber & Maunder, 2008; Committee on Fish Stock Assessment Methods et al., 1998). A major problem with this type of interrogation is that not all areas of interest are accessible, such as a private dock that is not open to the public (Committee on Fish Stock Assessment Methods et al., 1998). Interviewers may not be trained well enough to correctly identify a species. The spatial scale is so large that trying to accomplish this type of survey is fiscally impracticable. In order to mitigate the

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[38] The NOAA initiated the MRFSS in 1979 in hopes of capturing statistical data about recreational fishermen.

[39] The MRFSS is not used in all states. Some states don't participate in the survey at all.

[40] One key argument that is made is that the MRFSS has been unable to keep up with the ever-growing demand on fishery stocks, and it has not been able to take full advantage of recent advancements in mathematics, i.e., the survey is outdated, and current decisions are made on a set of data that has outlived its usefulness.

[41] There were so many deficiencies and recommendations that the NRC actually published a book outlining everything.

overwhelming cost in terms of both dollars and time that would be associated with point-access interviews, the telephone-access survey is used.

- The 2006 report also noted that the telephone-access survey is not without its faults. The intent of the survey was to detect and report on potential trends within fishery populations (McMurray, 2006). In order to maintain scientific credibility, the NOAA conducts a "random digit dialing" scheme along coastal communities (NRC, 2006). When the survey is conducted on the phone and a potential respondent is identified, the results may be invalidated because of the various exemptions—such as age or type of fishing—and a portion of the sampling population can be left out of the survey (NRC, 2006). This induces a bias if fishermen who don't want to share their results try to hide or falsify their information when contacted. Also, the phone-access surveys are restricted to coastal communities only; thus, they do not capture anglers that reside within the interior of the US (NRC, 2006).

- The survey does not account for fish mortality in the practice of "catch-and-release" fishing, meaning that some recreational fishermen who do not desire to remove any, some, or all of the fish caught during an excursion may exercise an option of releasing the fish after it has been caught (NRC, 2006). While this practice sounds like an effective employment method of non-consumptive practices, it almost certainly skews the total removal estimates (NRC, 2006). The catch-and-release method often injures, stresses, or kills the fish when it is caught (Hanna, 1998; Kleiber & Maunder, 2008; NRC, 2006). It has been estimated that 50% of the fish caught using this method will not survive (Kleiber & Maunder, 2008).

- Survey results may be inaccurate because species identification can be difficult for fishermen (Kleiber & Maunder, 2008). In other words, problems can arise when recreational fishermen who have little to no training in identifying fish species land their catch and have no idea what they have caught (NRC, 2006). The fishermen may inadvertently catch a species that is not to be caught (2006). Or, the fishermen may think they caught one species but, instead, have something completely different, and if surveyed, they may give an incorrect response as to what species that they have (2006).

- There is a potential for errors with the administration and analysis of the survey itself. In a study by Lee, Hu, and Toh (2000), they found that the length of a phone call can have an effect on how the information was reported to the surveyor. They discovered that if the phone interview went atypically long, there was a tendency to overestimate the information given (2000). Conversely, in the same report, they showed that in an atypically short phone interview, there was a tendency to underestimate the information given (2000). It was also discovered that with the ever-expanding cell-phone market, more adults that could be surveyed are not being interviewed[42] (Kennedy, 2007; Kanazawa, 2005; Lee, Hu & Toh, 2000). Some households may not have a traditional landline and rely solely on cell phones (Blumberg & Luke, 2007).

- Physical inputs into the MRFSS can also be negatively biased by the structure of the survey itself (NRC, 2006). It is common that individuals or groups of people not familiar with local fishing areas rent a private charter vessel that comes equipped with a captain and/or crew that are knowledgeable with the local fishing grounds (Committee on Fish Stock Assessment Methods et al., 1998; NRC, 2006). This local expert can direct fishing efforts to remove the maximum allowable take (Hsu & Wilen, 1997). Yet, the individuals on the charter vessels are not interviewed on the phone and will probably not be intercepted by the access-point interviewers (NRC, 2006). It is the sole responsibility of the crew if they wish to have any type of documentation on board, e.g., a logbook, which discerns the catch and where it was caught (2006).

c. Consumptive Commercial Use

Commercial fishing has long been a resource exploited for both financial and personal gain (Thrush et al., 1998). For instance, in Alaska it has been estimated that in the year 2001, commercial fishing landings netted $1.115 billion (Vaccaro & Sepez, 2003). Commercial fishing, unlike recreational fishing, is highly regulated and closely monitored because of the rapid depletion that can occur due to advancements in technology[43] (Jackson et al., 2001).

[42] MRFSS protocol dictates that cell phones can't be surveyed because they could have the potential for altering the locality parameter.

[43] Some of these technologies include more accurate "fish finders," global positioning systems tied into navigation software, the ability to deploy nets quicker and nets that are larger in capacity.

d. Regulation

The basis for commercial fishing regulation is rooted in the original 1976 *FCMA,* in which the first steps in creating the Exclusive Economic Zone were established. The spirit of this act was to save the US commercial-fishing industry for US fisherman[44] since up to that point, it had been exploited by foreign fleets (Hsu & Wilen, 1997). Because of this, the US fishing fleets were looking to the US Government to subsidize their ability to create a larger and more modern fleet (Hsu & Wilen, 1997; King, 1995). This action created two situations: 1) federally subsidized investment created a large domestic fishing fleet monopoly, and 2) the commercial industry had to accept federal fishery management (Hsu & Wilen, 1997).

As a result of the government's management plan, most of the fisheries in the US have a fixed number of vessels that are allowed to fish. This helps ensure oversight of the US commercial fishing industry. If there were no regulations (public or private) on how to administer fishing rights, then there would be significant potential for fishery access abuse (Hardin, 1968; Jackson et al., 2001). Fishermen would gradually increase the amount of time they spent in the fishery. In addition to the increase in time, there would be an increase in their ability to land fish through larger vessels or larger nets,[45] and there would be an increase in the actual numbers of fishing vessels in the fishery until the fishery collapsed[46] (Mullon, Freon & Curry, 2005). This was thought to be the case in the Caspian Sea, where the anchovy kilka (*Clupeonella engrauliformis*) fishery completely collapsed[47] (Daskalov & Mamedov, 2007).

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[44] The UN Law of the Sea Convention allowed for foreign fishing fleets to still operate in foreign waters until that country's fishing fleet was built up enough to handle the fishing capacity.

[45] The effects on undesired species would be devastating because of by-catch.

[46] A fishery collapse can be defined as a depletion of stocks to the point at which the species can no longer support active recruitment.

[47] As a result of a fishery collapse, new or different species will flourish and drive the numbers of the collapsing fishery even lower.

e. Non-consumptive, "Eco-tourism" Use

The utilization of environmental resources with a perceptible goal of enjoying the surroundings without the removal or intentional destruction of endemic species can be simply summed up to "eco-tourism" (Suman, Shivlani, & Milon, 1999; Swarbrooke, Beard, Leckie, & Pomfret, 2003). This is a growing, $110 billion (by some estimates) industry in the United States that shows no signs of slowing (Buckley, 2004; Johnson, 2002). As individuals become more aware of their potential impact on the earth and its resources, there has been a paradigm shift to "tread lighter" when enjoying activities outside (Buckley, 2004). These activities that are perceived to have a minor effect on the surroundings can, however, lead to an increase in undesired results (EcoHolidaying, 2008).

- (1) Impacts of "Eco-tourism." The general feeling regarding tourism based around the environment is typically viewed as having a positive influence on items such as conservation (Johnson, 2002). While this is the overall attitude, it should be noted that any increase in contact with the environment will cause a "foot print to be felt and left"[48] (Swarbrooke et al., 2003; Suman et al., 1999). As such, there have been increasing numbers in the recreational boating community in activities such as whale watching, diving or cruising (Swarbrooke et al., 2003). In an altruistic model, vessel operators that take part in such activities would only do so to maintain a living and would not cause a large impact to the environment. In practice, however, this is not the case. In the situation of dive boats, it can cost an operator $230,000 for outfitting and an additional $83,000 a year for maintenance alone (Suman et al., 1999). Such costs would motivate the owners to utilize their operation for as long as they can to recoup their expenses and to make a profit. In other words, large overhead incentivizes owners to push use beyond resource capacity.

f. RFID Use in Resource Management

What does all of this have to do with RFID? In light of the limitations outlined in the section on marine ecosystem management, it is clear that better systems of monitoring ecosystem use are needed. It is not within the scope of this paper to completely re-invent ecosystem management, but the authors do feel that the application of RFID technology to the task of monitoring small vessels, especially as opposed to an alternative such as the vessel monitoring system (VMS) currently required of commercial fishing vessels,[49] would create interesting and powerful possibilities with regard to data gathering. In particular, a registration system that incorporates RFID tagging of small vessels—and allows resource managers the ability to track and identify individual vessels in resource areas of interest—may enable regulators to produce a more accurate method for estimating recreational catch. For example, by correlating location and duration information for particular boats with calibrated landing data, RFID has the potential to be integrated into an ecosystem-based, marine spatial-planning framework.

In summary, the intricacies of homeland security and resource management are, at best, complicated. These issues involve many stakeholders who interact in a politically charged environment, and management problems are governed by multiple pieces of legislation. In this environment, implementation of any system is difficult. That being said, the use of radio frequency identification (RFID) technology, though not a "magic bullet," has the potential to greatly improve management challenges with regard to small vessels. RFID can provide greater access to information needed by decision-makers to help them provide security, safety, and resource management while posing less of a threat to the privacy of boat owners than both AIS and GPS monitoring.

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[48] Climbers are now experiencing trash problems on Mount Everest.

[49] VMS will not be addressed significantly in this paper because it is considered to be specific to commercial vessels and not applicable to recreational small vessels.

II. Methods and Materials

A. Beta Test

1. Study Site

To determine the feasibility of using an RFID system in this non-traditional method and to avoid wasting time and resources, the experiment was broken into two distinct segments. The first test was relatively inexpensive and took place on top of a multi-story hotel in the Monterey Bay area. If the system proved unlikely for success in this first test, then the airborne test would not have been pursued. The following sections cover the pre-trial tower test and the main airborne test.

The site selected for the pre-trial execution of testing RFID tags for their distance and speed capabilities was the rooftop of the Embassy Suites Hotel, located at the corner of Canyon Del Rey and Del Monte Avenue in Seaside, California. The site was chosen because the height at the tallest point of the structure provided as close of an analogous distance as possible, using Pythagorean's Theory of a2 + b2 = c2, relative to any other location within the area. As such, the north- and southbound lanes of Highway 1 were used for their ability to accommodate speeds analogous to an aircraft (see Figure 1).

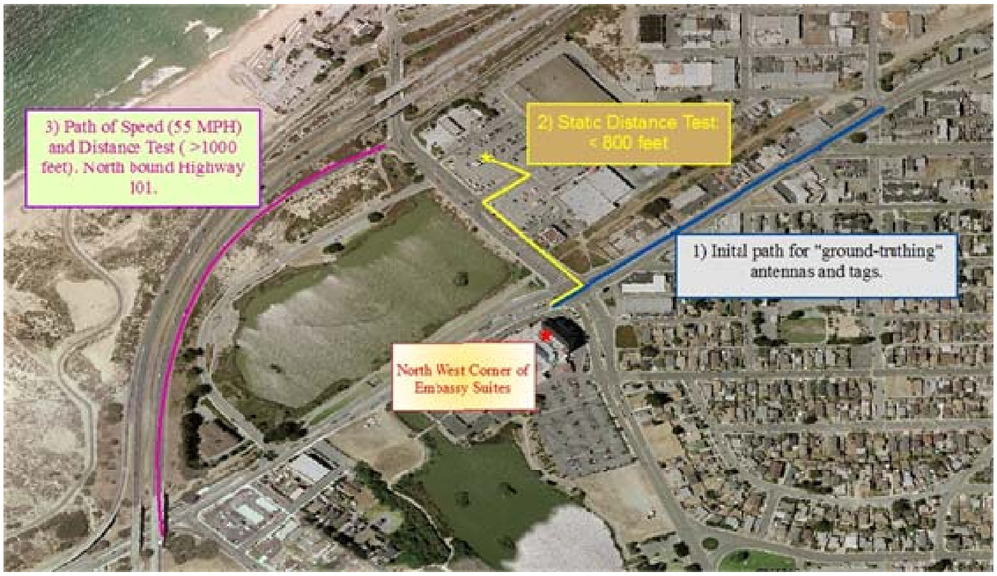

Figure 1. Graphical Representation of Paths Taken During Beta Test

a. Environmental Conditions

The test was conducted on May 12, 2009, from 1000–1600. The temperature was 63 degrees Fahrenheit. The sky was clear with no cloud cover, and a 5- to 6-knot wind was coming from the northwest.

b. Equipment

Savi Technologies, a division of Lockheed Martin, supplied engineering support in the form of multiple configurations of antennas, six active RFID tags, and an electrical engineer. The engineer had a personal laptop that he used to analyze real-time data from the RFID tags and antennas.

c. Antennas

Various standard Yagi directional hand-held aerial antennas (shown behind the interrogator module in Figure 2) were used opportunistically around the northwest corner of the building to obtain the best signal (see Figure 1). The antennas connected to the interrogator module via coaxial cables that were matched for the 433.92 MHz frequency range of the tags.

Figure 2. Photograph of One of the Antennas Used in the Test

d. Tags

The tags (see Figure 3) supplied by Savi Technology[50] were model ST-654 active RFID tags, which can operate in either beacon or poll mode. In beacon mode, the tags will continually broadcast their serial number at pre-determined intervals (usually every 10 seconds). In poll mode, the tags are "awakened" by a signal from the interrogator, and then they broadcast their serial number. In poll mode, because the serial number is broadcasted only when interrogated, battery life is extended, and the threat to privacy is reduced. In both configurations, the tags operate at 433.92 MHz. Six RFID tags were placed strategically around a blue 1999 Ford F-150 (see Figure 4) in the following manner: one on the rooftop horizontally, perpendicular to the vehicle's centerline; one on the dashboard horizontally, perpendicular to the vehicle's centerline; one on the inside of the rear windscreen vertically, perpendicular to the vehicle's centerline; one on the inside of the tailgate vertically, perpendicular to the vehicle's centerline; one placed opportunistically on the dashboard and allowed to "free float" as the vehicle was in motion; and one placed opportunistically within the cab of the vehicle, and allowed to "float freely" as the vehicle was in motion.

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[50] Savi Technology was chosen because they are a prominent RFID manufacturer with ample DoD and commercial RFID experience.

Figure 3. A Photo of Some of the Active RFID Tags

Figure 4. An Example of How the RFID Tags Were Placed (Note: This tag was placed on the roof of the vehicle and secured with Duct Tape.)

e. Real-time Tracking

Two hand-held Garmin GPS units (60CSx and eTrex Vista HCx) were placed within the tagged vehicle. These provided both a redundant tracking of the vehicle's movements, relative to a GPS waypoint taken from the northwest corner of the Embassy Suites, as well as the ability to correlate tracking waypoints to specific RFID hits. Each GPS unit was set to record waypoints every five seconds.

2. Pathways

a. "Ground-truth"

The antennas and RFID tags were "ground-truthed" with a course that was in a straight line with the best line of sight. The vehicle then travelled at given intervals of approximately 100 feet to investigate the maximum distance the tags could be read from the rooftop of the Embassy Suites (see Figure 1).

b. Static Distance

A second static test was devised as a means to investigate whether, at a distance greater than 800 feet, the antennas would have trouble reading the tags when in the proximity of other vehicles that were not tagged. That is, what would be the effect on the readability of the tags when surrounded by potential "noise"? As a result, a busy parking lot was chosen—with a clear line of sight—that was approximately 825 feet from the antenna (see Figure 1).

c. Dynamic Speed and Distance

A route was chosen along the Highway 1 northbound lane between the Fremont Boulevard entrance and Canyon Del Rey exit to provide for distances greater than 1,000 feet and allow for vehicle speeds to be constant at 55 miles per hour (see Figure 1).

3. Data Processing

The Garmin GPS files and RFID tag-read information were imported into Excel and correlated to extrapolate time to location and the RFID tag number. The Garmin GPS files and tag-read information were processed in ArcGIS 9.3 for analysis (see Figure 5).

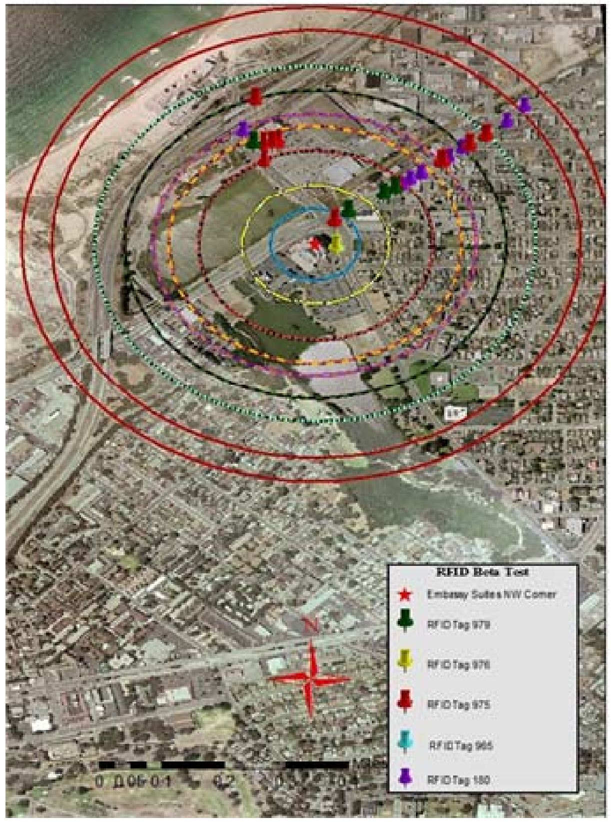

Figure 5. Graphical Display of All RFID Tags and Their Locations

B. Over-Flight Test

1. Study Site

The site selected for the over-flight was the Monterey Bay Marine Sanctuary, located in Monterey, California. The site was selected for the protection that the Monterey Bay could afford a small vessel from the influence of the California Long Shore current and any large ground swell that may have propagated offshore due to storm activity. The physical location for the over-flight was set to be five nautical miles offshore to comply with Federal Aviation Administration regulations regarding Class C controlled airspace around an airport, and to be well enough out in the Monterey Bay Marine Sanctuary to be able to fly below the 1,000-foot minimum threshold set by the National Oceanic and Atmospheric Administration's (NOAA) National Ocean Service for commercial and private air traffic (see Figure 6).

Figure 6. Graphical Representation of the Over-flight in the Monterey Bay Marine Sanctuary

a. Environmental Conditions

The over-flight was conducted on May 25, 2009. The temperature was 65 degrees Fahrenheit. The sky was overcast and assumed to have a ceiling of 1,500 feet. There was a 5- to 10-knot wind coming from the northwest. There was a perceptible ground swell that was approximately four to six feet in height, with a period of 13 seconds.

2. Equipment

a. NOAA Research Vessel Heron

The NOAA R/V Heron is a 19-foot Boston Whaler. It has a composite fiberglass hull. It was outfitted with an Evinrude outboard, 75-horsepower, 2-stroke engine. It has an open-deck configuration, i.e., no enclosed super structures.

b. NOAA Aircraft Twin Otter

The NOAA aircraft is a 52-foot Dehavilland Twin Otter outfitted with twin engine turboprops. It was chosen as the desired platform due to its ability to maintain a stable attitude while flying at slow speeds (i.e., the slowest it can maintain steady and controlled flight is approximately 80 knots).

c. RFID Antenna and Tags

The same RFID antenna and tags that were used for the beta test, were used in the over-flight.

RFID Tags: One tag was carried aboard the aircraft to ensure the antenna was working and reading correctly. The rest of the tags were attached throughout the vessel. Two tags were placed horizontally on the port side, parallel to the vessel's centerline (one forward close to the bow and one aft between the beam and transom). Two tags were placed horizontally on the starboard side, parallel to the vessel's centerline (one forward close to the bow and one aft between the beam and transom). Two tags were placed vertically on the helm station (port and starboard) at its highest point parallel to the vessel's centerline.

RFID Antenna: The antenna was used opportunistically on the starboard side of the aircraft through a transparent aperture.

d. Real-time Tracking

One hand-held Garmin eTrex Vista HCx GPS unit was placed on the tagged vessel to provide real-time tracking of the vessel's movements relative to the other Garmin 60CSx GPS unit aboard the aircraft. Each GPS was used to correlate against the RFID tags. Each GPS unit was set to record position, altitude, true heading, and speed every five seconds.

e. Over-flight Methods

The NOAA R/V Heron was left on station to conduct a drift study. It was noted that it was drifting at approximately 0.3 knots and would suffice as an analog for a recreational vessel engaged in fishing operations (see Figure 6). The outboard engine was left running due to mechanical issues. The Twin Otter conducted a series of over-flights such that the starboard aperture would always be facing the Heron. The Twin Otter was given a total of 1/2 a nautical mile on either side of the Heron to make its pass and circle back. The Twin Otter conducted 21 passes and flew varying speeds and altitudes throughout the exercise, with no less than a 500-foot floor and no more than a 1,000-foot ceiling (see Figure 6).

f. Data Processing

The Garmin GPS files and RFID tag-read information were imported into Microsoft Excel and correlated to extrapolate time to location and RFID tag number. The Garmin GPS files and tag-read information were processed in ArcGIS 9.3 for analysis (see Figure 6). Also, the same data was processed using Garmin's MapSource to analyze the flight patterns in Google Earth.

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III. Results of the Feasibility Experiment

A. Experiment Limitations

Under budget and timeframe restrictions, the experiment naturally had some limitations and artificialities that may not necessarily reflect real-world circumstances. For the individual tests discussed below, these limitations will be further explained. However, it should be noted that the goal was to prove feasibility of the technology in an airborne setting. The goal was not to test a large-scale employment of this system with numerous assets. That experiment requires an in-depth pilot study.

Other limitations are those of the technology itself. This experiment tested RFID in an environment for which it was not designed. Thus, the system has not been optimized for use in open-air and open-water situations. It can be expected that this limitation will diminish over the next decade as RFID technology improves with increased use by both industry and government.

Finally, every effort was taken to position the aircraft and the vessel in order to optimize the reception of the tags. This was accomplished not to skew or bias the data, but to ensure that sufficient quantities of data could be collected and analyzed. The RFID system itself was not modified; rather, the aircraft and vessel were positioned for maximum detection range.

B. RFID Long-Range Tower Feasibility Results

1. Test Objective

The objective was to test whether the system could successfully interrogate RFID tags from at least 1,000 feet slant-range distance from reader to tags. Since RFID has traditionally been used in warehousing and inventory management, the performance of the system in an outdoor environment with mobilized tags was unknown. One thousand feet was the threshold, because patrol aircraft often operate at or above 1,000 feet due to Federal Aviation Administration (FAA) restrictions and must obtain special permissions to descend lower.

2. Limitations of the Tower Test

Under the given conditions, the tower test could not fully replicate the upcoming flight test. The most prominent limitation was that the RFID reader was mounted on the fixed asset (the tower), and the tags were mounted on the moving asset (the truck). In contrast, in the flight test, the RFID reader was mounted on the moving aircraft and the stationary vessel carried the RFID tags.

Second, the tower test had to deal with the potential interference from communication antennas on the roof of the hotel and with ground clutter on the street surfaces below. Though not measured or verified, the potential existed for electromagnetic interference from the high-power receiver and transmitters used by Embassy Suites. The type and frequency of the arrays are not known, but analysis does not reveal any negative impact on the RFID readings. Also, the many flat surfaces of roads and buildings near the truck with the RFID tags may have interfered with the datum transmission, though again this was unmeasured and did not seem to negatively affect the readings.

3. Tower Test—Runs 1 & 2

With five tags mounted on various locations inside and outside the cab, the truck was slowly driven along a street vectoring northeast directly away from the tower. During this first run, radio contact between the driver and the tower allowed the tower crew to request the truck to stop when the RFID reader and antenna needed adjustment. The truck was driven away from the tower in increments of approximately 50 yards, after which it would pull over to the curb to wait for permission to advance. A handheld GPS receiver onboard the truck recorded the position of the truck every five seconds. This process continued until the tower crew could no longer acquire a positive read from any of the five RFID tags. At that point, the truck driver performed a U-turn and advanced back directly toward the tower in the same 50-yard increments. Using this method, multiple successful tag readings were captured, with distances out to nearly 2,000 feet. Figure 7 details the various locations of the truck for both Run 1 and Run 2.

Run 2 was performed in order to obtain additional information about the system's performance. A northeast direction was chosen because it offered a clear view from the tower (as opposed to the path in Run 1), and there was a higher density of moving vehicles and potential electromagnetic reflections. A four-lane highway and the Pacific Ocean were backdrops in this test. The geographic limitations of the roadways restrained Run 2's distance to only about 1,100 feet, though additional tag reads at these distances continued to support our hypothesis.

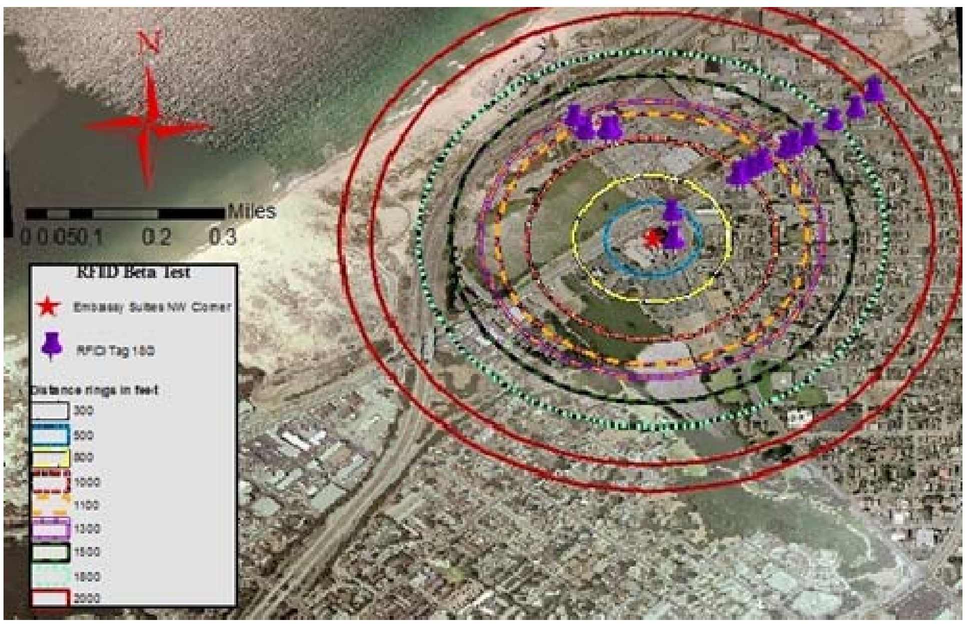

Figure 7. Successful RFID Reads for Tower Tests 1 & 2
(Note: The tower is in the center)
Imagery from ArcGIS®

4. Tower Test—Run 3

With the first two runs showing promising range results with relatively static tags, the third test evaluated the system with a moving target. The truck was driven on side roads and the four-lane Highway 1, located to the west of the tower. Due to the geography of the roadways and the newly discovered range of the tags, only a limited window on the highway offered promising results. Several runs were made at various speeds, with the truck traveling both north- and southbound. Over a 30-minute period, six passes were made at speeds of 30, 45, and 55 miles per hour. Between passes, the RFID reader and antenna were adjusted in an attempt to improve reception range. Throughout all of Run 3, only one tag was successfully identified and on only one occasion. Figure 8 shows the point (most northwesterly pin) at which the tag was identified at a range of approximately 1,400 feet while the truck was heading southeast at 56 miles per hour, or 49 knots.

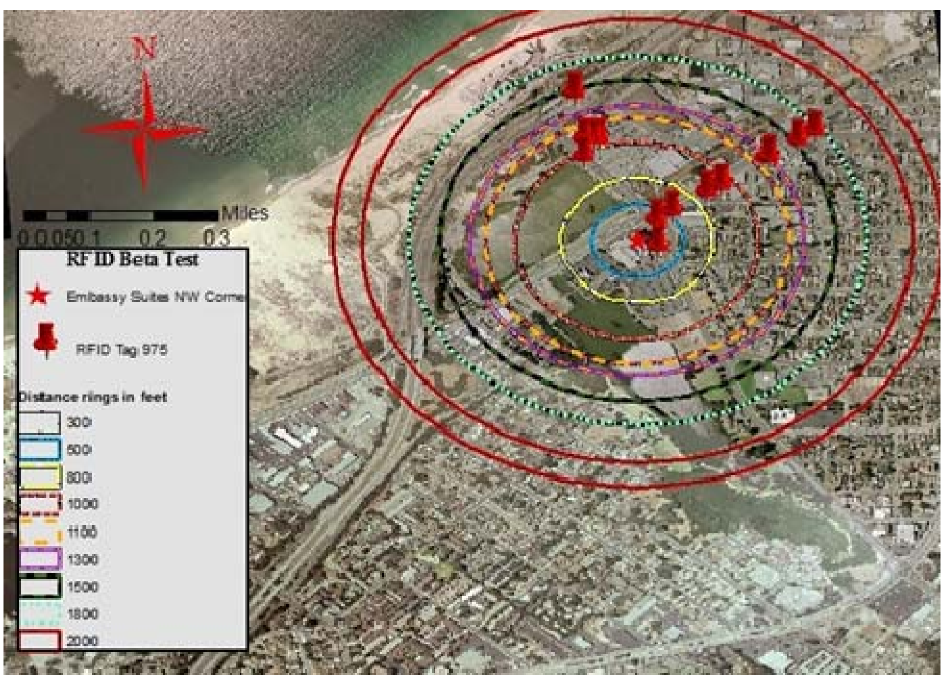

Figure 8. Run 3 Read Against a Moving Target at 49 Knots

This one successful tag reading did prove that the concept would work with a moving tag. However, one successful reading over six passes is a lackluster outcome, and it is doubtful that a monitoring agency would find these results acceptable for similar usage. Since the objective of the tower test was only to prove the concept before an airborne test was launched, the authors did not collect sufficient data to support or reject this particular feasibility test.

5. Summary of Long-range Tower Test

Since the one reading at 49 knots was approximately 50% of the normal operating speed of the aircraft that was planned to be used in the airborne test, the risk of continuing the feasibility experiment was considered moderate. However, because the static tests in the first two runs revealed ranges that exceeded the test threshold by nearly 100%, the tower test was deemed successful. Thus, the flight test was scheduled.

As stated previously, it is not the intent of this writing to conclude the feasibility of using RFID to track moving vehicles on the ground via a reader on a tower. Since the tower tests were used for risk-reduction to support the upcoming airborne test, the authors did not collect sufficient information to uphold or refute the feasibility of this particular application of RFID technology.

C. Airborne RFID Feasibility Test Results

1. Purpose of the Airborne RFID Test

The core of this feasibility writing is based on the airborne test in which an RFID interrogator is placed on an aircraft to identify RFID-tagged vessels on the water's surface below. The test was designed to answer the core question of whether or not a commercially available RFID system could perform this task at ranges outside the typical limitations of the technology. A threshold of 1,000 feet was set since most coastal patrol aircraft have a minimum operating limitation of 1,000 feet above the surface in populated areas (FAA, 2009).

2. Test Objective

The objective of this test was to determine if commercially available technology (which is available at the time of this writing) can be installed onboard patrol aircraft with minimum or no airframe modification and can be used to identify active-RFID tagged surface vessels during routine patrol operations. If feasible, research and development of the RFID technology is not required; thus, the acquisition, deployment, and sustainment can be accelerated to meet current requirements for vessel patrol and can be monitored by local and/or Federal Government agencies.

3. Limitations of the Airborne Test

This experiment was not a full-scale pilot study. As such, it was conducted with only one aircraft and one vessel in open-harbor waters. This was intentionally arranged to have as few variables as possible for the data analysis. Inferences about the feasibility of such technology in environments other than this experiment cannot be confidently made without further study on a larger scale and with additional resources.

Because the aircraft belonged to the National Oceanographic and Atmospheric Administration (NOAA) and time was limited for the experimental equipment design, the aircraft was not modified for optimum use of the RFID system. By typical aviation standards, the antenna installation was not compliant for constant usage. The full effects of this sub-optimal arrangement have not been studied and will not be addressed in this report. However, the system as installed did support our hypothesis with range readings well past the threshold limit.

A third limitation is that of any electromagnetic interferences that may have occurred between the aircraft systems and the RFID system. Before takeoff, the aircrew tested the instrumentation of the aircraft with the RFID system both on and off. No disturbances were noticed, and a safe flight was deemed possible.

However, the crew wisely elected to avoid Instrument Meteorological Conditions (IMC) while the RFID system was powered. As outlined in the Acquisition Strategy in Appendix A, the procuring agency for such a system must ensure that thorough electromagnetic spectrum interference testing be completed by the aircraft manufacturer or responsible agent. Additionally, the RFID system developer must ensure that the system's detection range capabilities are not severely hampered by the aircraft's electromagnetic field.

Analysis and testing for any possible electromagnetic interference between the outboard motor and the RFID tags were not performed. In order to identify any potential negative influences on the RFID tags mounted at various locations on the vessel, this type of testing should be accomplished in any future pilot studies.

D. Analysis of Data Collected

1. Vessel Path and Data

The vessel was launched into the Pacific Ocean one hour before aircraft takeoff and was positioned via GPS at a point five nautical miles off the coast of the Monterey Harbor. Five miles was required due to the Class C controlled airspace that the aircraft had to avoid. Figure 9 outlines the vessel's path to and from the test site. The green diamond indicates the position of the vessel during the start of the test, and the red diamond indicates the vessel's position at the end of the test. With ocean and wind currents, the vessel drifted at an average of 0.52 knots per hour, with one reposition occurring at approximately halfway through the flight test. The distance between the two diamonds in Figure 9 is 0.5 nautical miles. This drift has been accounted for in the analysis of the RFID system.

Figure 9. Vessel Location in the Pacific Ocean
(0.5 nm between diamonds)
(Imagery from Google Earth®)

2. Post-flight Data Analysis

The aircraft and the vessel were individually equipped with Garmin handheld GPS units, which logged the location, time, and altitude of the units every five seconds. Before the test, both units were time synchronized with a host laptop computer to ensure all time readings would be consistent. Figure 10 outlines the aircraft and vessel positions during the test, and Table 1 summarizes the 21 passes made by the aircraft.

Figure 10. Aircraft Path (thin black line)
(Imagery from Google Earth®)

Using Pythagorean's Theorem, the slant range was calculated for each pass's successful reading of the RFID tags. Read range is the delta between the two vehicles on a flat plane. Slant range takes into account the altitude of the aircraft and, thus, represents the true distance between the vessel and the aircraft. The bottom row of Table 1 shows the averages of the respective columns.

Table 1. Summary of Aircraft Passes and Reading Ranges

Pass #	Time Run Start	Time Overhead Vessel (PST)	Time Run End	Pass Duration	Altitude (ft)	Ground Speed (knots)	Heading (True)	# of Readings	Avg Ground Read Range (ft)	Avg Slant Range (ft) (Pythagorean)
1	2:03:22	2:03:52	2:04:27	0:01:05	700	80.8	251	2	2,029.97	2,147.27
2	2:06:38	2:07:28	2:08:14	0:01:36	700	75.6	224	1	1,624.24	1,768.66
3	2:08:54	2:09:29	2:10:14	0:01:20	700	99.1	100	3	2,100.26	2,213.84
4	2:10:49	2:11:19	2:12:09	0:01:20	700	129.5	234	0		
5	2:13:19	2:13:49	2:14:19	0:01:00	700	127.7	124	1	2,452.27	2,550.22
6	2:15:09	2:15:34	2:16:39	0:01:30	700	117.3	247	1	3,143.00	3,220.01
7	2:17:34	2:18:30	2:19:25	0:01:51	500	86.0	95	0		
8	2:19:55	2:20:35	2:22:00	0:02:05	900	70.4	252	2	1,971.56	2,167.27
9	2:22:55	2:23:35	2:24:20	0:01:25	900	98.2	101	0		
10	2:25:00	2:25:50	2:26:40	0:01:40	800	70.4	251	1	1,409.92	1,621.07
11	2:27:15	2:27:45	2:28:30	0:01:15	800	86.9	103	3	2,162.51	2,305.74
12	2:29:25	2:30:15	2:31:10	0:01:45	800	76.5	243	2	2,040.79	2,191.99
13	2:31:50	2:32:25	2:33:15	0:01:25	850	92.1	92	3	2,150.83	2,312.70
14	2:33:50	2:34:25	2:35:10	0:01:20	500	112.1	252	0		
15	2:36:05	2:36:40	2:37:25	0:01:20	500	100.8	91	2	1,677.34	1,750.28
16	2:38:10	2:38:55	2:39:32	0:01:22	500	90.4	222	0		
17	2:40:18	2:40:43	2:41:28	0:01:10	500	84.3	93	1	1,612.00	1,687.76
18	2:42:03	2:42:53	2:43:58	0:01:55	500	66.0	245	3	1,957.15	2,020.01
19	2:44:43	2:45:18	2:46:08	0:01:25	800	99.9	102	0		
20	2:46:48	2:47:38	2:48:28	0:01:40	800	97.3	255	1	2,262.05	2,399.35
21	2:49:18	2:49:53	2:50:23	0:01:05	900	89.5	112	2	1,307.51	1,587.32
Averages				1:27	702.4	92.9		1.333	1,993.43	2,129.57

Every successful pass resulted in a reading slant range over 1,000 feet. The minimum successful slant-range reading was 1,587 feet, and the maximum was 3,220 feet. Due to cloud cover, the aircraft was not able to climb more than 900 feet above the vessel, but the slant-range readings more than compensate for this limitation. In six of the passes (28.5%), no tags were successfully read. The parameters for these passes do not differ significantly from the other passes, and each falls near (both above and below) the average parameters for all 21 passes. In nine of the passes, there was more than one successful read per pass, with a maximum of three readings per pass. Of these nine multiple-read passes, five of them were readings from different tags on the vessel. The remaining passes showed multiple readings of the same tag during each pass.

The average pass duration was 1 minute, 27 seconds. A pass is defined as the time between: 1) the point at which the aircraft completes its turn and points toward the vessel for the interrogation run, and 2) the point at which the aircraft has completed its over-flight and begins to turn away from the interrogation heading. Pass duration obviously depends on aircraft speed and wind speed. Accounting for wind, the average speed of the aircraft was 92.9 knots during the 21 passes.

Figure 11 outlines the location of the aircraft when successful tag readings were made. 1,000-foot concentric rings have been overlaid to show the approximate range of the readings, though the rings are centered on a point in the water that represents the median location of the vessel during the duration of the test. The small fisheye dots represent the position of the aircraft when the vessel tags were positively identified.

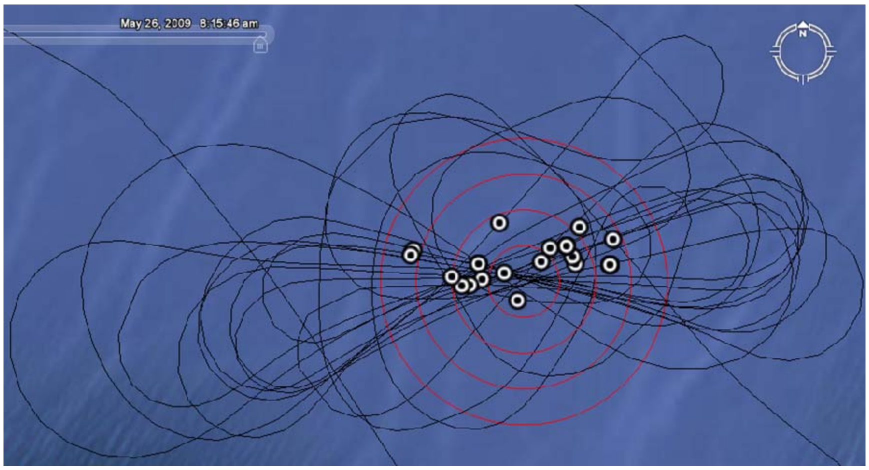

Figure 11. Overlay of 1,000-foot Concentric Rings and Location of Aircraft During Successful Tag Readings
(Imagery from Google Earth®)

The altitudes and speeds of each pass are graphed in Figure 12. The data does not reveal any limitations or preferences to a specific altitude as long as the aircraft was within the recorded maximum slant-range limitation of 2,129 feet, as seen in Table 1. Additionally, Figure 12 shows the spectrum of airspeeds for which the tests were conducted.

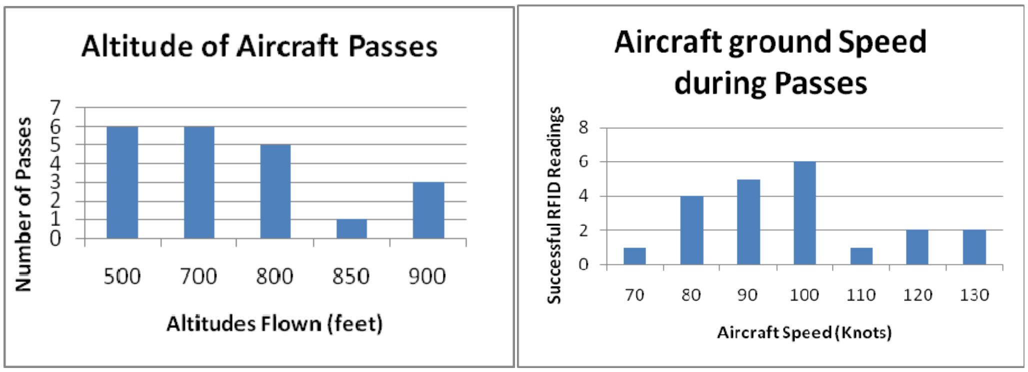

Figure 12. Altitude and Ground Speed of the Aircraft During Passes

The aircraft passes were performed mostly in an east/west orientation, with the vessel always pointing to the north. Figure 13 details the approach headings for all passes. Also detailed on the right side of Figure 13 is a breakout of all slant-range averages that were realized in the test. The minimum range of 1,600 feet and the mean range of 2,129 feet both far exceed the test objective of 1,000-feet slant range, resulting in a successful test.

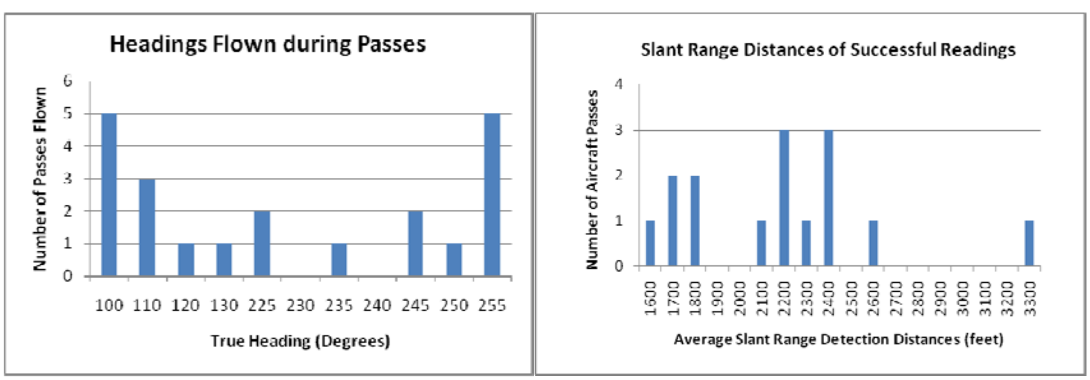

Figure 13. Left: True Headings Flown by Aircraft
Right: Average Slant-range Detection Distances

Regression analysis was performed between various data fields in Table 1. A summary of the R^2 values are shown in Table 2. Only test six revealed any significant correlation between the variables at a 95% confidence level. The slower the aircraft flew through the RFID tag interrogation range, the more time was available for the system to obtain a positive reading on one or more tags. While this finding is hardly groundbreaking, it does show that with the RFID tag configuration used a threshold airspeed exists that cannot be exceeded because the aircraft will fly in and out of range before the RFID tag can successfully respond. Figure 14 graphically depicts this trend. RFID tags with beacon rates less than every ten seconds will allow a faster aircraft to successfully read the tag because the quantity of tag transmissions increases per aircraft pass.

Table 2. Summary of Regression Analysis Performed

Regression Test #	Data Field #1	Data Field #2	R2 Value
1	Duration of Pass	# of Successful Reads	0.0017
2	Duration of Pass	Average Slant Read Range	0.0001
3	Aircraft Altitidue	# of Successful Reads	0.0438
4	Aircraft Altitidue	Average Ground Read Range	0.0484
5	Aircraft Altitidue	Average Slant Read Range	0.0643
6	Aircraft Speed	# of Successful Reads	0.1641
7	Aircraft Speed	Average Slant Read Range	0.0276

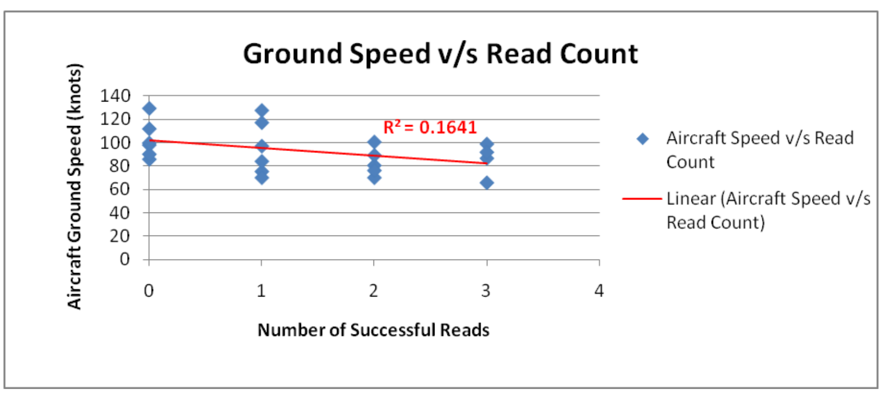

Figure 14. Regression Analysis Test Number Six

E. Summary of Results

Despite electromagnetic ground clutter and potential interference from high-power communication antennas on the roof of the tower, the RFID system performed well and successfully recorded 111 interrogations of the tags during the tower test. Out of these, the maximum range observed was nearly 2,000 feet, and one reading was at 1,400 feet while the tag was moving at 49 knots.

The subsequent flight test revealed that the RFID system onboard the aircraft successfully identified RFID tagged vessels on the water's surface. Of all the passes, 71.5% returned successful, with multiple tag readings that exceeded the 1,000-foot test objective by 59%–222%. Agencies that would use this Airborne RFID system could successfully conduct over-flight monitoring while complying with the 1,000-foot minimum altitude threshold set by the National Oceanic and Atmospheric Administration for marine sanctuaries and the Federal Aviation Administration for congested areas.

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IV. Feasibility Test Conclusions and Discussion

A. Hypothesis Supported

As explained in the previous section, the commercially available RFID system was successfully tested in two incremental steps in order to assess the feasibility of outdoor and long-range usage for aircraft implementation. The first test was conducted from the top of a multi-story hotel, with the tags mounted on a moving vehicle on the streets below. Despite electromagnetic ground clutter and potential interference from high-power communication antennas on the roof of the tower, the RFID system performed well and successfully recorded multiple tags on 111 occasions. The maximum range recorded was nearly 2,000 feet, and, on average, the distance read during this initial test was 982 feet (see Figure 15). Interestingly, one particular reading was at 1,400 feet while the tag was moving at 49 knots.

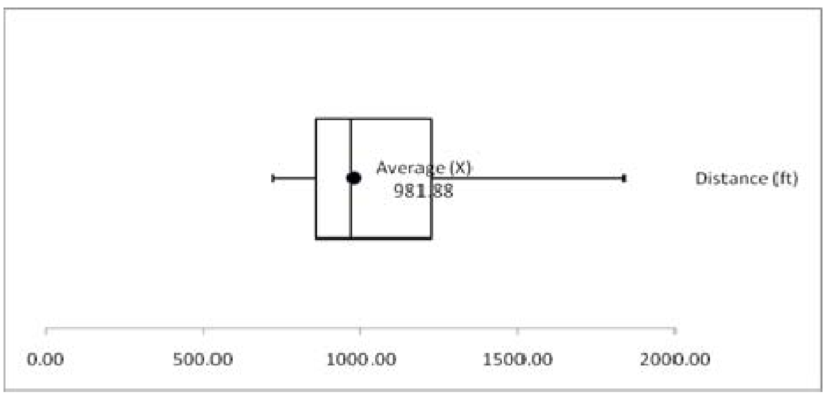

Figure 15. The Range of Readings from the Initial Test was Approximately 850 to 1,200 Feet

During the subsequent flight test, the aircraft was flown over the vessel 21 times at various altitudes and speeds. 71.5% of the passes returned successfully, with multiple tag readings that exceeded the 1,000-foot test objective by at least

59% and up to 222%.[51] From this data, we can conclude that it is possible to read a commercial off-the-shelf RFID tag mounted on a small vessel using a commercial off-the-shelf RFID interrogator mounted on aircraft. With tag detection ranges out to 3,220 feet (4,414 feet with outliers included[52]), and an average detection range of 2,129 feet (2,105 feet with outliers included, see Figure 16), we can also conclude that an aerial RFID system has significant potential to support waterway patrol operations from airborne assets. Thus, our findings support the concept of integrating RFID-based assets into small-vessel monitoring systems.

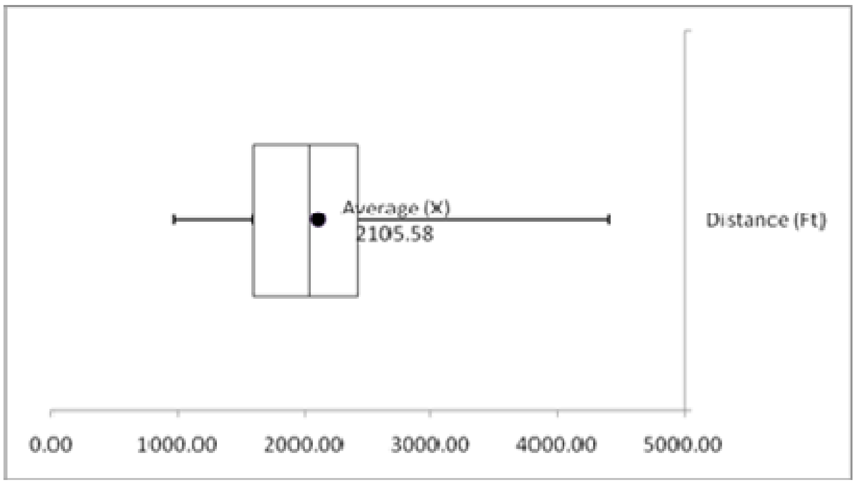

Figure 16. Range of Readings From the Over-flight Test (with outliers included)

1. Implications of Findings

Chokepoints, which are defined here as physical restrictions through which all vehicles must pass, are found in nearly all land-based transportation environments. Trains run on continuous chokepoints because the rails allow for no deviation in

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[51] The threshold value of 1,000 feet divided by the minimum & maximum slant range observed (1,587 and 3,220 feet).

[52] Outliers were included in the box plots (see Figures 15 and 16) as a function of attempting to capture all of the data. The outliers were recorded during aircraft over-flight setup runs but were excluded in other calculations because the official over-flight tests with specific speeds and altitudes had not started.

course, and automobiles follow streets and pass through intersections. Even the seemingly open sky is separated into precise corridors and layers of airspace that are constantly monitored, and most aircraft must eventually land in places that are also monitored. In aquatic environments, however, physical chokepoints only occur at places such as industrial complexes, harbor entrances, canals, straights, and river mouths. As with other transportation environments (as noted by Crofts, 2007), these chokepoints are ideal points to place monitoring systems. However, unlike the other transportation environments mentioned, these chokepoints represent a relativity low percentage of the 10,758[53] nautical miles of coastline in the United States ("United States," 2009). The monitoring of waterways, therefore, requires a system that can be used over long ranges and is flexible enough to work in various environments and coastal conditions.

The authors hypothesized that aircraft equipped with RFID readers could meet these needs. This feasibility study proved that commercially available RFID equipment can be used to successfully identify surface vessels from airborne platforms that operate within speed and altitude envelopes similar to the Dehavilland DHC-6 aircraft. Most law-enforcement aircraft (both fixed wing and rotary) fall within this speed range, as do many Unmanned Aerial Vehicles or Systems (UAV, UAS). In combination with land-based, RFID-monitored chokepoints, the ability to patrol even the most remote areas with RFID-enabled aircraft makes RFID a viable suggestion for maximizing information and coverage per unit of monitoring effort, per dollar spent.

The RFID system used in this test is commercially available. Government procurement would require no research and development of the technology—only modifications of settings and mounts—and such systems could be used on-board

[53] The coastline is defined as the land bordering an area of water that stretches out 12 nm to the US seaward limits of the US territorial sea and 200 nm to the limits of the US Exclusive Economic Zone.

any pre-existing patrol/rescue aircraft. Aircraft modification would be minimal since receiving antennas can be made to fit into a variety of forms at a low cost.

The authors are not advocating immediate adoption and procurement of an airborne RFID system. Rather, they are suggesting that such a system at least merits further examination in various conditions, equipment types, and quantities, and, ideally, the initiation of a pilot study.

However, it should be mentioned that the limited results of this study suggest that if a system like the one tested were employed onboard an existing airframe with flight characteristics similar to the DHC-6 and if RFID tags were deployed onto vessels of interest, then an agency could potentially identify those vessels with this system, even in an unmodified state.

B. Study Limitations and Artificialities

The above scenario is predicated on the weather, equipment, and angular conditions tested in this feasibility experiment. Thus, inferences about how well the system will perform outside the tested parameters cannot be confidently made; however, the system did prove robust enough to perform in the physically and electronically cluttered setting on top of the hotel in the tower test and was able to overcome ad hoc aircraft mounting procedures and interrogation methods in the flight test. These limitations can be verified or ignored when additional large-scale testing of the system is accomplished. Still, there are limitations and artificialities that deserve mention in this study.

The first limitation was the fact that only one vessel was available for testing. Additional vessels of various sizes, hull types, engines, and speeds should be tested to ensure that the RFID system would work equally well with each permutation. Having multiple RFID tags on the one vessel increased the quantity of data collected; however, this multiplicity cannot be used to replicate the many variables and effects that different vessels would have on the RFID readings.

Stagnant data is a second limitation of the system as tested. Immediately upon successful interrogation of a tag, the system added an entry to the database. However, since the system was not connected to a data transmitter, only the aircrew had access to the information. Moments later, the vessel would be in a different location, and the data collected would become increasingly useless. If the goal of the aircrew were to collect a snapshot in time of vessel readings for historical purposes, then this setup would be sufficient. However, it is more likely that agencies would prefer to know in real-time the location of vessels and, as a result, would want access to the interrogation database. Any means of data communication would be sufficient for this purpose, and minimal bandwidth would be required. Over the course of the one-hour mission, the system recorded 408 rows of data, arranged in 45 columns that ranged from tag serial number to tag battery status to tag humidity-sensor status. The file size was only 116 kilobytes (KB) and would not require any encryption since no personally identifiable data was included in the tag readings. Transmitting the interrogation data to a real-time data-analysis network would allow agencies to respond to trends or findings without having to wait for the aircraft to land and manually offload the information.

Coupled with the above limitation is the fact that the RFID system is not a location-detecting system. Like most radio frequency emitters, RFID is omni-directional and does not use any space- or land-based navigation signals for orientation or alignment. When a tag is successfully interrogated, the time of the event is recorded, but the distance and location are not known. Because the average slant reading range in this feasibility test was 2,129 feet, a successful reading meant that the tag was somewhere inside an invisible sphere with a radius of 2,129 feet and centered around the RFID tag itself. To build a composite diagram of vessel locations, the aircraft's position must be known, constantly logged, and correlated to the RFID system's database. This can be accomplished manually—as was performed in a spreadsheet on the flight data in this feasibility test—or automatically if GPS or INS data were to be fed into a common database with the RFID system. Alternatively, the aircraft could transmit positional data via the aforementioned communication link, and the ground agency could correlate the RFID readings with the aircraft positional data. However it is accomplished, the two system clocks need to be slaved to a common time signal to ensure the most accurate data is documented.

The successful discovery of RFID's potential for long-range vessel interrogation creates a complimentary and problematic issue that must be understood and accounted for in vessel-interrogation sorties. Because the RFID system is omni-directional, as mentioned above, it is also ambiguous as to the exact distance from the interrogator to the RFID tag. For example, if a tag were to have a maximum reading range of 2,129 feet, then the aircraft could fly directly overhead the tagged vessel and get one reading. Imagining the invisible RFID sphere around the vessel, the aircraft would come in tangential contact with the sphere at exactly one point, 2,129 feet away from the vessel. The tangential point represents the vessel's location to a high degree of certainty because interrogations at any other points on the sphere are not possible due to the 2,129-foot range limitation. Conversely, if that same aircraft were to fly at 1,000 feet above the tagged vessel, then the aircraft's geometric plane of flight would intersect into the invisible sphere and inject a circular area of probability in which the vessel could be located. In this situation, the aircraft would not be able to determine the exact location of the vessel and would only be able to assume that it is located no more than 2,129 feet away, but it may also be much closer. Realistically, the maximum detection range of individual tags cannot be known and is likely not a constant value over time due to atmospheric and electronic fluctuations. Thus, the airborne RFID system as tested cannot be used to verify the precise position of vessels on the surface. It should be noted, however, that the authors have considered the possibility that exact positional data could be gained with the use of a small rotary UAV/UAS by hovering at low altitude over a vessel of interest. For example, if a sighted vessel was not supposed to be operating in a certain area, and enforcement officials needed to determine definitively what the position of that vessel was in relation to the prohibited area, then an RFID- and camera-equipped rotary UAS could hover at an altitude high enough to be a safe distance away from the vessel, but low enough to consider the aircraft's position the same as the vessel under it. The UAS could document the vessel's presence at that location and at that time with photographic and RFID evidence.

An additional artificiality of this feasibility test was the fact that the interrogation system and the antenna were mounted ad hoc in the aircraft without engineering analysis of any airframe properties that may have impeded successful interrogation events. Having little time and money to produce this experiment, the authors could not obtain permission in time to rigidly mount the antenna either inside or outside the aircraft. Rather, it was hand-held during the sortie and placed next to an observation window on the starboard side. Commercial 433 MHz antennas are available for aviation use and could be mounted in multiple configurations or quantities to maximize the detection capability of the airframe. More robust testing with rigid-mounted antennas would alleviate the unknown implications of the hand-held performance in this feasibility test.

As outlined in Chapter I, the use of RFID for vessel interrogation must be coupled with additional sensors or detectors if 100% identification is required. If an aircraft were to overfly 100 vessels, this study concludes that 71 of them would be successfully interrogated[54] in the first pass. If there were only one pass, the remaining 29 vessels would not be identified and logged. For some agencies, this percentage is wholly acceptable for a general survey that contributes to long-term trend analysis in which complete accuracy is not necessary. It would also be acceptable if RFID were being used to determine the identification and status of vessels that were seen visually and that were actively targeted for reading. Conversely, for scenarios requiring more accurate read-rates, the current RFID system either needs to be tailored more specifically for the marine and aerial

[54] 71% is based on the 15 successful passes out of 21 total passes demonstrated in this feasibility study.

environment—and read-rates improved to approach 100%—or it must be coupled with a complimentary monitoring system. With such a system, any vessel that is overflown but not successfully interrogated by the RFID system will alert the aircrew of a vessel that has either no tag, a faulty tag, or needs to be re-interrogated. If the density of vessels on the surface is low, then human eyes in manned aircraft may suffice for comparison of visual count and RFID readings. However, this is not optimal, especially when visibility is low, and the aircrew is busy with normal aircraft navigation and piloting duties. Potential complimentary systems could be based upon infrared camera technology, low-power radar, or sonar. A future study of the application of Airborne RFID will reveal strengths and weaknesses of each candidate system.

C. Concepts of Operations (CONOPS) and Employment

As mentioned in the Introduction, the first requisite of RFID CONOPS is the requirement for all small-vessel owners to mount an RFID-based license tag at an optimal location on their vessel. This is an inexpensive proposition, estimated at around or less than $45–$77 per vessel. This is also minimally invasive since the PII corresponding to these licenses would necessarily be maintained as a network-accessible database by a single agency, with controlled and selective access by other agencies that have a need to know. The establishment and management of such a database would be the most costly component of this system but may be offset by the alternate uses such a database may offer.

Subsequently, the authors envision an expansion of a system in which fixed RFID interrogators are used to monitor bottleneck waterways for anomalies. Combined with other surveillance technology—which can independently detect vessels and investigate negative tag responses—the fixed system would create a persistent monitoring capability in highly sensitive areas.

For occasions when information is needed on vessels that are not in the vicinity of fixed systems, the authors recommend modifying currently available RFID antennas to conform to a uniform, modular, open-architecture mount that would be universal to all manned and un-manned aircraft employed by the DHS, DoD, and NOAA. As with the fixed systems, the mounted RFID hardware would be relatively inexpensive and non-developmental. As with the fixed system, the more costly element in this aerial system would be the development of the database interface that would allow real-time interaction between the aircraft and the database.

D. Areas for Future and Additional Research

The aforementioned limitations and artificialities of this airborne RFID feasibility study all point to the need for additional studies to be completed before an agency wholly adopts the system as a viable solution for vessel monitoring. We have proven only that RFID can be used at acceptable ranges in an air-to-surface arena; a large-scale pilot study would expand the understanding of airborne RFID's abilities, limitations, and applications. A pilot study should consist of numerous vessels in various locations that are allowed to operate normally over the period of weeks or months. During that time, various aircraft missions could be generated and flown into the tagged vessel's area(s) of operation. Ideally, the missions would be performed at various times of the day, in diverse weather and sea conditions, and over various geographical locations. Other potential variables to be tested would be antenna types and placements, tag manufacturers, operating frequencies, response settings, and aircraft-operating envelopes. The overall goal would be to examine trends in tag-detection levels and error-reading rates.

Additionally, optimal over-flight patterns, routes, and tactics could be identified for aircraft usage and aircrew orientation training upon deployment of the airborne RFID system. To support a pilot study, agencies could request RFID manufactures to enter into Cooperative Research and Development Agreements (CRADAs), in which various RFID tags and interrogators could be trial-tested and compared.

A second area of further research would revolve around meshing the interrogation database with inter-agency and intra-agency databases. As mentioned in the limitations section above, the RFID tags only transmit the serial number of the tag, and no personally identifiable information can be collected in the airborne RFID database—much like a license plate on an automobile typically reveals nothing about the driver's personal information. Ideally, this serial number will be logged into an RFID tag-registration database—much like a Department of Motor Vehicles' (DMV) registration database. The vessel owner's information could be synchronized with the aircraft's interrogation database, if the need were to arise. Additionally, this registration information could be linked or shared with other government or law-enforcement agency databases to enable national security goals or analysis. Law-abiding vessel owners would likely never be matched or correlated in this manner. However, if national security agencies needed information about particular individuals of interest, the RFID database would supply additional information about the habits and locations of vessel(s) owned by those individuals.

Airborne RFID could potentially be linked into a network of sensors that constantly monitor national coastal areas and harbors. Additional studies could examine how airborne RFID and land-based RFID chokepoint stations (Crofts, 2007), traffic cameras, AIS, and other monitoring technologies could be meshed into the same database to develop composite situation and trend pictures of vessel movements and patterns. Emerging advances in payload and mission duration of UAVs and UASs reveal that airborne RFID could be mounted to a loitering UAS that constantly monitors coastlines and transmits readings back to ground stations or up to satellite receivers. Thus, airborne RFID could play a pivotal role in national-security sensor fusion, intelligence collection, and trend analysis.

Finally, additional research should be applied to the use of less expensive RFID equipment. As technology constantly improves, so does the potential for smaller, lighter, and more powerful RFID tags to be used for airborne applications. As the price of each tag decreases, the ability for an agency to procure more tags for more vessels increases. Thus, any previous usage and implementation issues due to tag cost could be minimized or eliminated.

Further, the range of passive RFID tags may improve sufficiently that they could replace active RFID tags for airborne RFID application. Currently, passive RFID tags do not have enough transmission power to reach out more than a few feet. This is because they utilize power inducted from the interrogation signal to retransmit their serial number. Because magnetic induction replaces the battery found in active tags, passive tags are smaller and much less expensive. Future advancements in either passive tag design or in interrogator waveform patterns or techniques could bring passive tags into the Airborne RFID arena.

E. Summary of Conclusions

With the hypothesis confirmed and the feasibility test showing that RFID can indeed be used onboard an aircraft to interrogate and monitor surface vessels, agencies can now plan scenarios for a pilot study and future vessel-monitoring operations using this commercially available technology. In doing so, agencies must be aware of the limitations of this experiment and plan accordingly for shortfalls in the solution itself. Depending on the desired outcome, agencies could use airborne RFID in the same manner as tested in this experiment, or they could link the data into new or pre-existing databases for real-time monitoring operations that are synchronized with inter-agency or intra-agency information sources. In addition, advances in technology and unmanned vehicles should be peripherally monitored to ensure that airborne RFID is updated when necessary to embrace emerging capabilities and enhancements.

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V. Abbreviated Business Case Analysis

A. Purpose of Cost Analysis & Summary of Results

As noted in Chapter II, this paper considers the strengths and weaknesses of an Airborne RFID system for use by an agency tasked with small-vessel management for the purposes of coastal patrol or protection. The objective of this chapter is to 1) outline the potential stakeholders who may utilize or be affected by implementation of an Airborne RFID system, and 2) roughly approximate the costs and benefits that the system may have to the stakeholders listed below. It is not within the scope of this chapter to examine the costs of all aspects of an RFID system, or alternative technologies that may serve as effective small-vessel monitoring systems. Such an endeavor would best be undertaken with a future pilot study. This chapter is intended only as a primer to such a pilot study and to complete the analysis of implementation issues.

In summary, for the notional 300-linear-nautical-mile geographical area shown in Figure 17 and described in section D, the total estimated cost to implement an Airborne RFID system is $149,164. This includes the non-recurring cost of procuring the interrogation equipment and installing it in all necessary aircraft. The benefits for the first year are estimated to be $601,500. Figure 18 shows that the port/coastal security and the resource-management stakeholders glean the highest ratio of benefit-to-cost. Little if any immediate benefit can be expected for agencies—which bear the largest burden of the implementation costs—tasked with issuing/maintaining vessel registration and RFID tags. Figure 19 combines the total costs and benefits and displays each stakeholder's ratio of impact.

B. Analysis Assumptions

- Agencies must implement some vessel monitoring system and cannot choose inactivity or the status quo.
- Airborne RFID is the chosen technology.

- The equipment costs are based on the current prices found in Appendix A of the notional Acquisition Strategy, which is based on the commercially available prices found at the time of this writing.
- Some costs are intangible, and thus are subjectively estimated. When such subjective estimations are used in this report, the data will be annotated as to how the estimate was calculated.
- All estimates are made in FY10 US dollars and are not adjusted or discounted for present or future values.
- The cost of "black box" secure mobile communication connections, such as the Joint Tactical Radio System (JTRS) are already in development for other purposes and available to agencies with a need for secure network transmission from aerial platforms. As a result, the cost of integrating RFID network access at this level is considered to be a sunk cost and, therefore, negligible for the purposes of this chapter.
- A centralized or regionalized database containing vessel registration data is considered to be already existent, and thus, no costing of development, implementation, or connections is performed in this cost-benefit-analysis CBA.
- RFID-tag batteries are expected to have an operational life of 2 years before needing replacement.
- Agency aircraft are assumed to be preexisting in the inventory, and regularly fly mission profiles over the areas of interest. No new or additional missions will be required for Airborne RFID flights. Existing mission profiles, with RFID interrogators on-board, are sufficient for vessel monitoring operations.

C. Potential Stakeholders

The following is a list of stakeholders who may directly employ or acquire an Airborne RFID system, or in some direct way are affected by its implementation. For alternative implementation methods, the potential stakeholder list may change significantly. However, this particular list is premised on the notional implementation scenario outlined in section D of this chapter and is intended to orient the reader to the multiple participants and roles needed for an Airborne RFID system to be employed.

1. Agencies Tasked with Providing Port and Coastal Security

- Description of responsibilities:
  - Responsible for the monitoring of vessel traffic, vessel quantities, vessel safety and identifying potentially hazardous situations in which vessel traffic exceeds port or coastal-authority management abilities.
  - Responsible for monitoring port and coastal areas for suspicious or illegal activities performed by vessel operators.
  - Responsible for remotely identifying and monitoring vessels in areas of interest for coastal and port security by increasing the amount and quality of real-time information on those vessels, which would help identify anomalies that are likely to pose a threat to shore-side or floating targets of interest.
- Connection to the Airborne RFID System:
  - This agency is the primary recipient of the collected RFID data, which can be used to execute the responsibilities listed above.

2. Agencies Tasked with Managing Resources

- Description of responsibilities:
  - Responsible for the protection and management of coastal natural resources. Typically, these resources are in the form of flora or fauna, or fragile coastal ecosystems that require human intervention for safeguarding.
  - Responsible for limiting, restricting, or barring vessel traffic or resource use for specific or extended periods of time.
  - Responsible for recording measurements of coastal use and resource consumption for conservation records and trend analysis that contribute to management decisions.
- Connection to the Airborne RFID System:

- A direct customer of the data collected from the Airborne RFID system.

- Able to utilize the correlation of location and identification data collected from recreational vessels to help develop effective catch estimations, and contribute to forecasts that can aid resource management.

3. Aviation Units Tasked with Supporting other Stakeholders

- Description of responsibilities:

    - Directly or indirectly tasked by port & coastal security, resource management, or law enforcement personnel who require an airborne presence over an area of interest for the purpose of interrogating the vessels for RFID tag information.

    - Responsible for collecting and disseminating RFID-tag interrogation data, which will be generated when the airborne asset has been sent into an area of interest.

    - Responsible for maintenance, upkeep, and repair of the RFID interrogator system and the various sub-components that are necessary for data collection.

    - Responsible for the orientation, training, and certification of qualified aircrew members who are able to employ and troubleshoot the interrogation system onboard the aircraft.

- Connection to the Airborne RFID System:

    - The aviation units represent the interrogation and data collection portion of the Airborne RFID system. The aircraft owned by this agency will be outfitted with the interrogator module, the antenna, the collection software, and the various cables and power cords necessary for safe airborne operation.

4. Agencies Responsible for Law Enforcement

- Description of responsibilities:
    - Responsible for the safety and protection of the citizens who live on and near the coastal area(s).
    - Responsible for the monitoring and enforcement of local, state and federal laws.
    - Responsible for coordinating efforts with the coastal security and resource management agencies when enforcement situations require joint efforts over both land and sea.
    - Connection to the Airborne RFID System:
    - Primary users of Airborne RFID system when agency aircraft are engaged in patrol, when monitoring activities that originate, transect, or conclude in a coastal area of interest, and when analyzing trends between any law enforcement and vessel registration databases.

5. Private Vessel Owners

- Description of responsibilities:
    - Responsible for registering their vessels with the appropriate vessel registration agency and complying with all vessel owner and water use ordinances and laws.
    - Responsible for following RFID-tag mounting instructions given to them by the vessel registration agency and ensuring the RFID tag is not blocked or damaged during the expected life of the battery.
    - Responsible for replacing the RFID-tag battery that is issued to them by the vessel registration agency during the periodic re-registration periods.
- Connection to the Airborne RFID System:
    - The vessel owners represent the RFID-tag user population. The tags, which are affixed to their privately owned vessels, may be interrogated by the aviation unit's aircraft when the vessels are in areas of interest.

6. Agencies Tasked with Issuing/Maintaining Vessel Registration and RFID Tags

- Description of responsibilities:
  - Responsible for maintaining a record of all vessels and the owner's information in databases that can be accessed by port security or law-enforcement agencies.
  - Responsible for issuing RFID tags to vessel owners when vessels are registered with the agency.
  - Responsible for recording the RFID serial number into the agency database, which can be correlated to the vessel owner's information.
  - Responsible for issuing RFID replacement batteries when vessel registration renewals are processed, or when vessel owners request to purchase additional replacement batteries.
  - Responsible for receiving, storing, inventorying, and reordering RFID tags to ensure all registered vessels are issued one RFID tag.
- Connection to the Airborne RFID System:
  - This agency acts as the enabler for all current and future vessels to receive an RFID tag.
  - This agency links the RFID serial number to the vessel registration number.

D. Notional Implementation Scenario

The following scenario is a notional coastal area based on the following assumptions and key factors. Figure 17 depicts a hypothetical geographical area that may embody many of these elements.

- The coastline has one major port, one minor port and numerous small harbors.
- The coastline is approximately 300 linear statute miles.

- A random distribution of vessels can be found throughout the area of concern.
- A random distribution of vessel types can be found throughout the area of concern (e.g., composite, metal and hybrid hulls; commercial and private fishing crafts, and recreational crafts).
- There will be minimal to non-existent overlap with aircraft over-flight. This will allow two aircraft to survey 150 linear statute miles each.
- Within the 300-mile operational area, either the upper or lower limit will have contact or overlap with a marine sanctuary under the purview of the Resource Manager Stakeholders.
- An airport is within the operating area that can accommodate the aircraft, provide an area for securing the aircraft and allow for the Aviation Stakeholders to perform maintenance and have access to secure data transmission methods.
- Law enforcement and/or Security Stakeholders should have a minimum of one intercept vessel (size, endurance and support of the vessel should be proportional to port size).

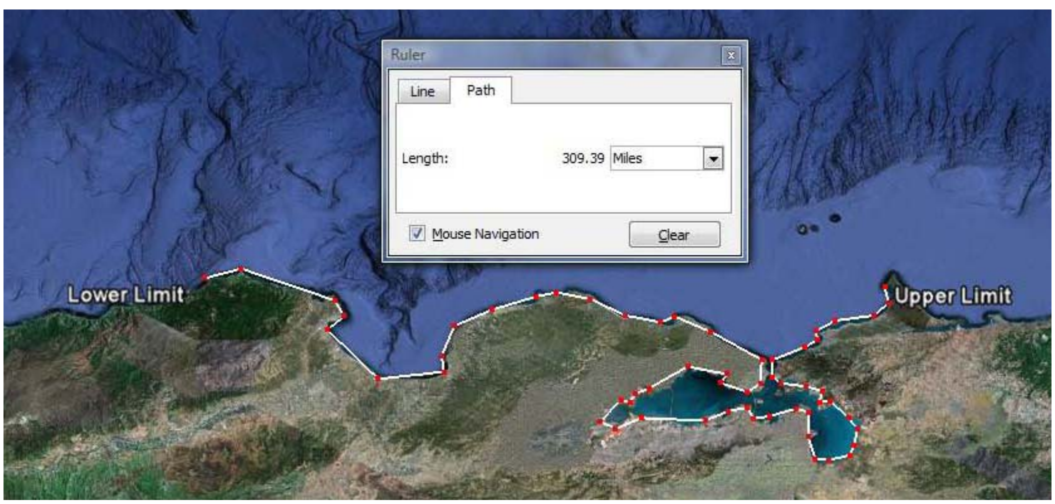

Figure 17. Hypothetical Geographical Area
(Imagery from Google Earth®)

E. Cost/Benefit Analysis

The following lists of potential costs and benefits are a rough order of magnitude estimates and are expressed, where possible, in FY10 US dollars. Agencies are stakeholders, as outlined above, and are within the bounds of the notional implementation scenario in Section D above. One man-year is equal to 2,000 hours of labor. A notional cost of $50 per hour is used in all calculations.

1. Agencies Tasked with Providing Port and Coastal Security

Costs: $13,000 per year

- -$13,000 per year, per agency
  - **Reason:** Labor necessary for periodic aggregation of collected RFID data from other stakeholders
  - **Basis of estimate:**
    - 5 hours per week x 52 weeks = 260 man-hours

Benefits: $324,000 per year

- +$180,000 per year, per agency
  - **Reason:** Reduction in labor hours required due to reduced monitoring and loiter time in areas of interest. Labor that typically patrols areas of interest can be tasked elsewhere in the agency. Labor that typically covers all 300 nm of the scenario can now be covered by two aircraft.
  - **Basis of estimate:**
    - 300 nm broken out into 20-mile patches can be monitored by 15 vessel crews
    - Each crew of 2 members spends 5 hours per day on patrol
    - 2 members x 5 hours per day x 30 days = 300 hours per month

        - 300 x 12 months = 3,600 hours per year = $180,000

- ➢ +$144,000 per year, per agency
    - o **Reason:** Labor hours saved due to reduced monitoring and patrol of vessels in the two ports. Crews can reduce the number of patrol cycles by 50% due to better visibility from the Airborne RFID platform(s).
    - o **Basis of estimate:**
        - Both harbors are monitored by 1 crew each, with 2 members per crew
        - Each crew spends 8 hours per day on patrol
        - 2 members x 8 hours per day x 30 days = 480 hours per month
        - 480 x 12 months = 5,760 hours per year = $288,000 x 50% = $144,000

2. Agencies Tasked with Managing Resources:

Costs: $13,000 per year

- ➢ -$13,000 per year, per agency
    - o **Reason:** Labor necessary for periodic aggregation of collected RFID data from other stakeholders
    - o **Basis of estimate:**
        - 5 hours per week x 52 weeks = 260 man-hours

Benefits: $273,600 per year

- ➢ +$129,600 per year, per agency
    - o **Reason:** Labor hours necessary for monitoring and patrol of vessels in the marine sanctuary can be reduced by 90% since the Airborne RFID can replace surface operations.

- o **Basis of estimate:**
  - ▪ One vessel with a crew of two members must patrol the sanctuary once every day for 4 hours.
  - ▪ 2 members x 4 hours x 30 days = 240 hours per month x 12 months = 2,880 hours per year
  - ▪ 90% of 2,880 = 2,592 hours = $129,600

➢ +$144,000 per year, per agency

- o **Reason:** Reduction in required number of visual vessel inquiries in order to retrieve and record the registration number of vessel(s) in the marine sanctuary.
- o **Basis of estimate:**
  - ▪ One crew member with binoculars taking approximately 10 minutes per vessel to approach, verify, and record the registration number and notes on any activities.
  - ▪ Estimating 10 vessels per hour, per 8-hour day = 80 vessels divided by 10 minutes = 8 hours per day x 30 days x 12 months = 2,880 hours = $144,000

3. Aviation Units Tasked with Supporting Other Stakeholders

Costs: $17,650 per year (includes $12,240 non-recurring)

➢ -$12,240 one time cost per unit (with 2 aircraft)

- o **Reason:** Equipment costs and installation for 2 aircraft
- o **Basis of estimate:**
  - ▪ 2 interrogators ($2,000 each) = $4,000
  - ▪ 2 antennas ($70 each) = $140
  - ▪ 2 laptops ($1,000 each) = $2,000
  - ▪ 2 software licenses ($2,300 each) = $4,600
  - ▪ Labor (15 hours per aircraft) = $1,500

- -$13,000 per year, per unit
    - **Reason:** Labor necessary for periodic aggregation of collected RFID data and dissemination to other stakeholders
    - **Basis of estimate:**
        - 5 hours per week x 52 weeks = 260 man-hours

- -$2,400 per year, per unit
    - **Reason:** Labor necessary for periodic maintenance and repair of the RFID interrogator system. One major maintenance repair procedure per year in which the equipment is fully removed and reinstalled.
    - **Basis of estimate:**
        - 3 hours per month x 12 months = 36 man-hours + 12 hours per year for major maintenance = 36 + 12 = 48 = $2,400

- -$2,250 per year, per unit
    - **Reason:** Labor necessary for initial training and periodic refresher training for operators who will utilize the RFID interrogator system during patrol flights.
    - **Basis of estimate:**
        - Initial training: 5 hours per year, per crew member (2) + 1 instructor = 3 members x 5 = 15 hours = $750 x 2 aircraft = $1,500
        - 3 hours per year of refresher training for 4 members and 1 instructor = 3 hours x 5 members = $750

Benefits:

- Benefits for the aviation units are likely only intangible and incalculable. One remote possibility is for security agencies that benefit from Airborne RFID to increase support funding to the aviation units due to patrol-mission cost reductions.

4. Agencies Responsible for Law Enforcement

Costs: $13,000 per year

- -$13,000 per year, per agency
  - **Reason:** Labor necessary for periodic aggregation of collected RFID data from other stakeholders
  - **Basis of estimate:**
    - 5 hours per week x 52 weeks = 260 man-hours

Benefits: $3,900 per year

- +$3,900 per year, per agency
  - **Reason:** Reduction in labor hours required due to reduced monitoring and patrol time in areas of interest. Labor that typically patrols areas of interest and responds to situations in which enforcement is needed can be tasked elsewhere in the agency. Time and labor expended coordinating with other agencies about vessel registration data can be reduced if the law-enforcement agency has access to the latest Airborne RFID readings.
  - **Basis of estimate:**
    - Estimating two false-alarm situations per week that could have been avoided if Airborne RFID records were consulted first (finding that a vessel is actually still in port, for example).
    - Each false-alarm response requires 45 minutes of action and post-action paperwork.
    - 2 situations x 0.75 hours x 52 weeks = 78 hours per year

5. Private Vessel Owners

Costs: $64 per year

- -$64 per year, per vessel owner
  - **Reason:** In addition to the cost of vessel registration or renewal, owners must purchase the RFID tag and a new battery every two years.
  - **Basis of estimate:**
    - Initial cost of tag (average market value) = $61 (high price of $77 and low price of $45)
    - Annual cost of battery replacement = $4 ($8 battery purchased every two years)

Benefits:

- Benefits to the private vessel owners are likely only intangible and incalculable. One remote possibility is that security agencies that benefit from Airborne RFID may be able to decrease vessel registration and fishing license fees due to patrol-mission cost reductions.

6. Agencies Tasked with Issuing/Maintaining Vessel Registration and RFID Tags

Costs: $80,210 per year

- -$13,000 per year, per agency
  - **Reason:** RFID tags must be managed, stored, issued, and restocked.
  - **Basis of estimate:**
    - 5 hours of labor per week to manage inventory, receive new tags, and properly dispose of expired batteries.
      - 5 hours per week x 52 weeks = 260 man-hours per year

- -$54,210 per year, per agency
  - **Reason:** Ten minutes extra time is required per vessel registration to pull a tag from inventory, enter the number into the registration database, and instruct the vessel owner on how to properly install the tag.
  - **Basis of estimate:**
    - Assuming 25 vessel registration or renewals per day, 25 x 10 minutes = 250 additional minutes per day, or 4.17 hours per day
      - 4.17 hours x 5 days per week x 52 weeks = 1,084.2 hours
- -$13,000 per year, per agency
  - **Reason:** Labor necessary for periodic dissemination of vessel registration and RFID-tag data to other stakeholders or law-enforcement databases
  - **Basis of estimate:**
    - 5 hours per week x 52 weeks = 260 man-hours per year

Benefits:

- Benefits to the registration agency are likely non-existent. RFID-tag issuance, if accomplished by this type of agency, would only add additional duties and responsibilities. Agencies that benefit from Airborne RFID should consider attempting to offset additional labor costs levied on this agency.

F. Cost/Benefit Summary

From a combined agency and stakeholder perspective, an estimated positive benefit of $452,336 for the first year is the predicted outcome. This amount overshadows the initial investment costs and builds a strong case towards the support of this small-vessel monitoring system.

A summary of the estimated costs and benefits are displayed in Table 3. The resultant ratios are graphically displayed in Figures 18 and 19.

Table 3. Estimated Cost & Benefit Summary by Stakeholder

	Port/Coastal Security	Resource Managers	Aviation Units	Law Enforcement	Private Vessel Owners	Vessel & Tag Registration Managers	Totals
Estimated Costs	($13,000)	($13,000)	($29,890)	($13,000)	($64)	($80,210)	**($149,164)**
Estimated Benefits	$324,000	$273,600	$0	$3,900	$0	$0	**$601,500**
Total	**$311,000**	**$260,600**	**($29,890)**	**($9,100)**	**($64)**	**($80,210)**	**$452,336**
Cost-to-Benefit Ratio per Stakeholder	3.86%	4.54%	100.00%	76.92%	100.00%	100.00%	
Benefit-to-Cost Ratio per Stakeholder	96.14%	95.46%	0.00%	23.08%	0.00%	0.00%	
% of Stakeholder Cost to Total Costs	8.72%	8.72%	20.04%	8.72%	0.04%	53.77%	**100%**
% of Stakeholder Benefit to Total Benefits	53.87%	45.49%	0.00%	0.65%	0.00%	0.00%	**100%**

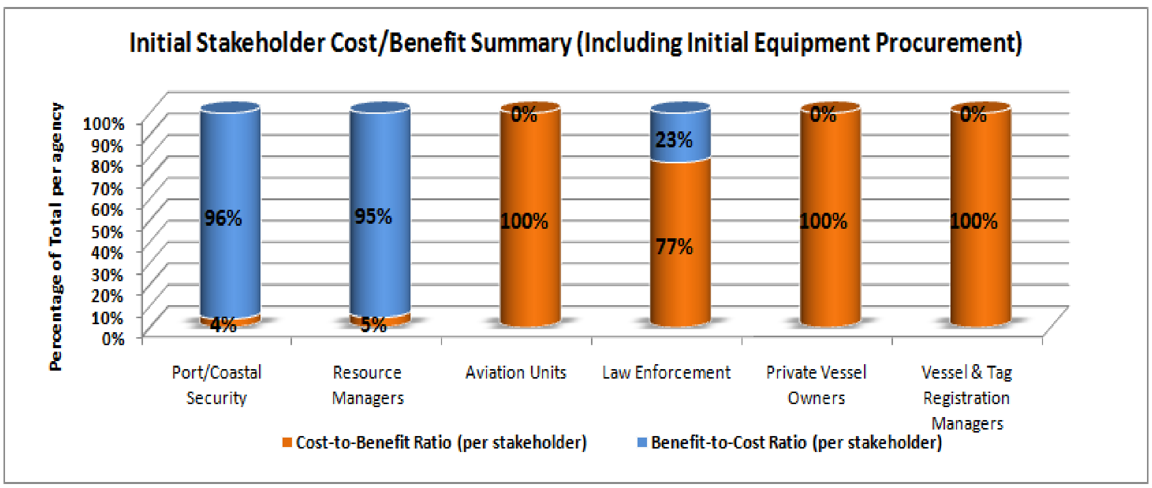

Figure 18. Estimated Cost & Benefit Summary by Stakeholder

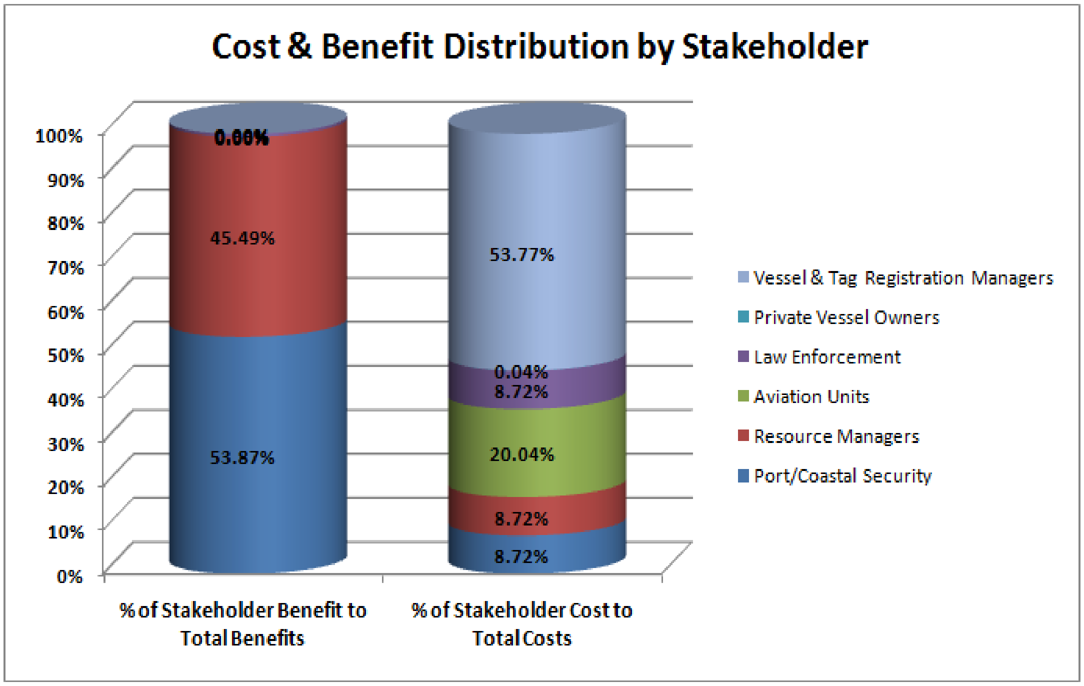

Figure 19. Cost & Benefit Distribution by Stakeholder

Under the circumstances outlined in this abbreviated cost/benefit analysis, implementation of an Airborne RFID system merits further examination by agencies that may perform similar responsibilities as those listed in the stakeholder list in Section C of this chapter. In future studies, plans must be made to ensure that the various stakeholders understand their roles and responsibilities and the impacts levied by the introduction of such a system.

Appendix A. Notional Acquisition Strategy

A. Concept of Operations & Equipment Use

1. General Overview

Appendix A outlines a plan for rapid procurement of commercially available RFID technology by a US Government agency for the purpose of monitoring moving vehicles from airborne platforms. Leveraging the results from the successful feasibility study outlined in previous chapters, the authors feel that a complete research and development strategy is not necessary to get this capability fielded in short order. Thus, this strategy will only examine the facets needed for procurement and implementation of commercial off-the-shelf (COTS) technology and any minimal airframe integration measures. This appendix will not stand alone as a procurement guide, but instead, it will serve as a strategy guidebook for program-office officials using the *Department of Defense Instruction 5000.02* principles (USD(AT&L), 2008).

Starting with an examination of a potential concept of operation for an airborne RFID system, this guide will examine equipment standards to replicate the results of this experiment and the programmatic steps necessary to procure, field, and maintain the equipment. The solution proposed is only for the RFID equipment and any integration engineering required for installation onto *existing* airborne platforms.

2. Potential Concept of Operations (CONOPS)

There could be numerous methods and arrangements made by organizations to procure and utilize an Airborne RFID system. This particular concept of operations seeks to suggest one possible method, though acquiring agencies may have unique and better methods suited for their particular needs. Within this particular guide, COTS equipment procured for this Airborne RFID system will be divided and annotated generally into three categories: 1) interrogation equipment, 2) RFID tags, and 3) data processing equipment. Hereafter, the three categories will be referred to as readers, tags, and data processors. Also, the combined components will be referred to as the Airborne RFID system.

After procurement, readers and data processors could be sent to the gaining agency's aviation units, where they will be affixed to existing aircraft in the inventory. They will be added to the unit's inventory list, and ownership will be transferred to the resource managers. Tags will be sent to an issuing agency for dispersal with existing vessel registration procedures. Tags will remain the property of the procuring agency, thus a data-sharing agreement will be required to ensure the procuring agency and the aviation units are aware of the locations of all tags issued to the public.

The aviation units will incorporate the readers into their existing flight operations and missions, allowing the RFID technology to be run either as primary or secondary mission tasks. During flights, tag data will automatically be recorded by the readers if the aircraft is flown into the proximity requirement of the RFID technology. The aviation units will be required to transfer the reader data to the data processors upon completion of the mission and to maintain the readers according to technical order specifications supplied by the procuring agency.

3. General Equipment Requirements

The reader used in the feasibility experiment was a Savi Technologies SP-652-111 module designed to operate in the 433.92 MHz range, using a standard directional 9 dBi Yagi antenna and a 12-volt, direct-current power supply. The reader weighed approximately 2 lbs and the antenna and cabling collectively weighed approximately six lbs. The reader and antenna units are built to comply with FCC signal requirements.

The tags used were Savi Technology ST-654 active RFID tags developed for the US Navy and operated at 433.92 MHz. Savi's EPtool software was used to collect the data onto a laptop, which was running Microsoft Windows XP operating system. EPtool is not for sale to the public, but Savi does offer similar products that perform similarly to EPtool.

To replicate a system like the one tested in this feasibility study, Table 4 outlines the suggested threshold and objective values. Threshold values summarize the equipment used in the feasibility test. Objective values must be tailored to specificorganizations and any unique requirements they may have. Note that *DoDI 5000.01* requires each successive increment of procurement to have its own set of threshold and objective values (USD(AT&L), 2008, p. 13).

Table 4. Airborne RFID Threshold/Objective List

	Threshold	Objective
Reader Size & Weight	2-3 lbs	Airframe Specific
Reader Frequency	433.92 MHz	433.92 MHz and other RFID tag frequencies that may potentially be used
Reader Environmental Limitations	Temperature: -32°C to +70°C Humidity: 100% Vibration & Shock: MIL-STS-810E Method 15.4, Category 10	Vessel or Organization Specific
Tag Size & Weight	Size: 6.25" x 2.125" x 1.125" Wt: 3.8 ounces	Vessel or Organization Specific
Tag Frequency and Power Output	433.92 MHz at 0.6 mW	Organization Specific
Tag Battery Life	10 Sec Beacon Mode: 1 Year Pole Mode: 3 Years	10 Sec Beacon Mode: 2 Years Pole Mode: 5 Years
Tag Beaconing Frequency	10 seconds to replicate experiment	<10 seconds for more readings per aircraft pass
Tag Environmental Limitations	Vibration & Shock: MIL-STD-810E, method 15.4, Category 10 Temperature: -32C to +70C Humidity: 100%	Airframe Specific

4. Communication of Limitations of Airborne RFID Solution

Procuring organizations should explain clearly to requirement agencies that the Airborne RFID system studied in our experiment has many limitations and cannot serve as a standalone system for complete monitoring, tracking or surveillance of vessels. Chapter IV of this project outlines the results and observed identification ranges of the system. These limitations are expected to diminish over the next decade as RFID technology improves with increased use by industry and government.

5. Modular Open Systems Architecture (MOSA)

Program managers, "shall employ MOSA to design for affordable change, enable evolutionary acquisition, and rapidly field affordable systems" (USD(AT&L), 2008, p. 79). The proposed Airborne RFID system and the ever-evolving pool of COTS RFID technologies are best procured using a MOSA methodology in government acquisition processes. Early determination by the procuring agency that the Airborne RFID system will be only a portion of a large data-gathering network—and not a one-unit/one-manufacturer system—will ensure that future RFID technologies can be leveraged quickly, without interruption to on-going data-gathering missions. A complete explanation and implementation guide for MOSA can be found in the DoD guidebook, *A Modular Open Systems Approach (MOSA) to Acquisitions* (OSD, 2004).

The Airborne RFID system can be procured under MOSA rules, if the procuring agency avoids RFID manufacturers who build proprietary reader/tag interfaces. If proprietary RFID tags are issued en masse, then the procuring agency must recall and reissue these tags if they wish to upgrade later to a different manufacturer. This will inevitably incur undue, and possibly large, expenses.

B. Suggested Program Office Structure

1. Program Office Organization

Procurement of this Airborne RFID system will not require the establishment of a new Program Management Office (PMO). Because the technology for this system is commercially available and involved Research & Development (R&D) will not be required, procurement and management work levels will have minimal impact on an existing PMO. Management of Airborne RFID procurement activities would best align with existing electronics, communications, or information technology PMO's that have at least one Acquisition Category Level Three (ACAT-III) program already underway. Depending on the workload of the PMO, this system could be managed by one of each of the following properly trained acquisition personnel:

- Program Manager—Defense Acquisition Improvement Act (DAIWA) Program Manager Level 2 or higher certification
- Systems Engineer—DAIWA Systems Planning, Research, Development and Engineering Level 1 or higher certification
- Lifecycle Logistics Engineer—DAIWA Lifecycle Logistics Level 1 or higher certification

The above personnel must have periodic access to financial, contracting, and legal representatives in the PMO for contract and financial administration services.

2. Funding & ACAT Designation

The equipment used in the feasibility test (see Chapter III) has an estimated commercial value of $5,986. This price includes one of each of the first four items in Table 5 and eight tags. Because the quantity of tags will vary with the desired population that the agency wants to track, the price of the tags has been omitted from funding calculations in this section.

Table 5. Cost of RFID Equipment Used in Experiment

Item	Estimated Cost Per Item (FY09 Dollars)
Reader Module & Cables	$2,000
Reader Antenna	$70
Data Processing Software License	$2,300
Laptop with Microsoft Windows XP or Vista	$1,000
RFID Active Tags (Eight used @ $77 each)	$616
Total	$5,986

Assuming that a notional agency will procure forty units[55] for the coast lines of the continental United States, the total initial procurement cost will be approximately $214,800 (FY09 dollars).[56] Table 6 outlines the price of ten units for each region's acquisition. Of course, this does not include the price of tags, which would vary depending on the agency's concept of operations and how many vessels they would plan to monitor.

Table 6. Estimated Regional Cost to Procure Ten Units (not including tags)

Quantity per Region	Item	Estimated Cost Per Region (FY09 Dollars)
10	Reader Modules & Cables	$20,000
10	Reader Antennas	$700
10	Data Processing Software License	$23,000
10	Laptop with Microsoft Windows XP or Vista	$10,000
	Total per Region	$53,700

DoDI 5000.02 designates Acquisition Categories (ACATs) according to total Research, Development, Test & Evaluation (RDT&E) estimates, (USD(AT&L), 2008,

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[55] This is based on dividing the United States into four regions and assigning 10 systems per region for coastal use only. The notional regions would be A) Northwest Coast & Alaska, B) Southwest Coast & Hawaii, C) Northeast Coast down through Virginia, and D) Southeast Coast from North Carolina down to the Gulf of Mexico.

[56] This cost is only a rough estimate and is only shown here to inform the reader that this project is in thousands of dollars, and not millions. It is calculated as $53,700 x 4 regions.

p. 33). Thus, if the agency desires to start a new program for Airborne RFID, it would qualify as an ACAT-III. Additionally, this system would not qualify as a Major Defense Acquisition Program or Major Automated Information System and would be exempt from the extra oversight and report generation required with those designations.

An alternative to seeking ACAT status would be to locate an existing program with congressional approval that is generic enough to procure data collection or tracking systems. Under such blanket approval, and using a MOSA approach, an office would not have to wait to receive an ACAT designation.

C. Product Lifecycle and Evolutionary Acquisition

DoDI 5000.02 states that the evolutionary acquisition approach is the "preferred DoD strategy for rapid acquisition of mature technology" (USD(AT&L), 2008, p. 13). Figure 20 outlines this process, which allows rapid delivery of capabilities in increments. Though the technology for an Airborne RFID system is COTS available, following the evolutionary acquisition approach would ensure important aspects of the product lifecycle are considered and managed.

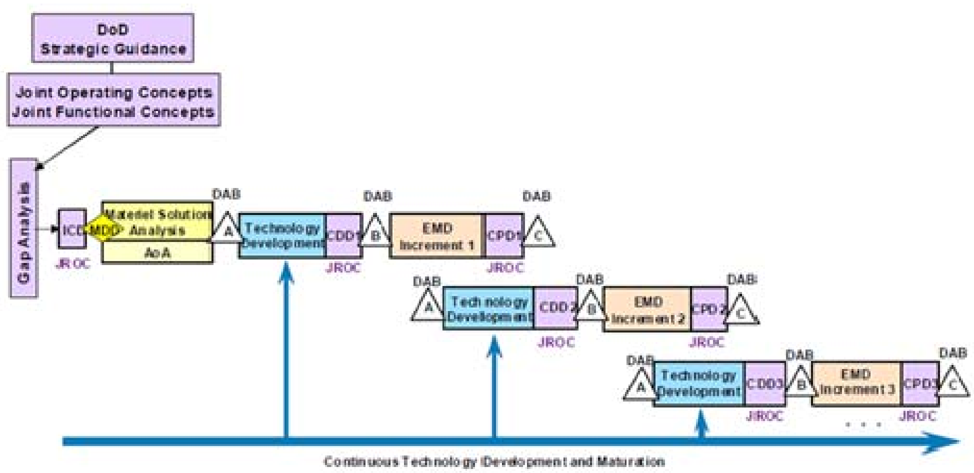

Figure 20. Requirements and Acquisition Process Flow
(USD(AT&L), 2008, p. 13)

This report will concentrate on the core programmatic functions outlined in Figure 20 and the *DoDI 5000.02*. Requirements functions, labeled with names like Guidance, Concepts, CDD, and/or CPD, are functions of the user community and are thus only peripherally discussed. This report assumes the user community has deemed the Airborne RFID system to be worth procuring and has therefore completed the required processes to obtain authorization and appropriation through the Planning, Programming, Budgeting & Execution System (PPBES) of the DoD. Note also that Figure 20 does not depict the production, deployment, and operations of each increment, which occur after the Milestone C triangles.

1. Materiel Solution Analysis Phase

This first phase is mandatory for all programs and is the formal entry point into the acquisition process. It is designed to examine the various materiel solutions in the market and, thus, will augment the formal Analysis of Alternatives (AoA) study performed by the requirement owners. A major goal of this Airborne RFID feasibility study is to accelerate this phase and the generation of the AoA. Having a completed research report and associated price estimate with performance statistics should eliminate much of the time ordinarily needed for this type of analysis. The exit criteria for this phase are a "complete[ed] AoA, a proposed materiel solution, and full funding for the next phase" (USD(AT&L), 2008, p. 16), which will be required for the Milestone A review.

2. Technology Development Phase

For a typical acquisition program in which R&D is required, this phase is used to bring the concept into a prototype form. Building from the Milestone A approved material solution, funds would be spent to form drawings from ideas and forms from drawings.

For Airborne RFID, this phase has also been substantially shortened due to this feasibility study. *DoDI 5000.02* states that technology "procured from industry or other sources shall have been demonstrated in a related environment or, preferable, in an operation environment to be considered mature enough to used for product development" (USD(AT&L), 2008, p. 19). Chapter III of this project outlines the test environment in which the Airborne RFID system was studied. With aircraft airspeeds equivalent to most airborne assets and weather conditions on the ocean consistent with typical coastal days, we argue that the test represents an operational environment. If the user representatives in the PMO agree with this assessment, then the *5000.02* regulations allow program advancement to the Milestone B review.

A more conservative approach would be to conduct market research according to *Federal Acquisition Regulation (FAR)* Part 10 and 12.202 to solicit companies to report on any similar relevant/operational demonstrations with RFID and airborne assets. We were unable to find any firms that had performed this type of research.

3. Engineering and Manufacturing Development Phase

This feasibility experiment was performed with a DeHavilland DHC-6 Twin Otter turboprop airframe operated by the National Oceanic and Atmospheric Administration (NOAA). Details of the equipment installation, antenna orientation, and flight profiles can be found in Chapter III. If the acquiring agency desires to equip their existing DHC-6's, then this study may slightly accelerate the Engineering & Manufacturing Development phase. For procuring agencies that will use other airframe types, this phase will require a higher level of effort than previous phases.

The purpose of this phase is to develop a complete, full system article upon which supportability, usability, and affordability tests can be conducted. Full program funding is required because contracts will be issued to a company after a source selection is complete. Beyond the typical information supplied in solicitations, a list of recommended additional considerations when writing the Request for Proposal (RFP) includes the following:

- Outline or provide specifications for interface with the specific airframe that the Airborne RFID system will be installed on,[57]
- Request airframe-specific mounting methods for the RFID antenna,
- Request airframe-specific antenna options—internal or external and price/performance trade-offs,
- Request airframe-specific flight profiles for the best interrogation conditions,
- Request RFID system shielding techniques and subsequent navigation and instrumentation interference levels,
- Request center-of-gravity correction calculations to account for weight,
- Request expected aircraft performance impact(s), if equipment will be mounted in the airstream,
- Request Federal Communications Commission equipment certification,
- Request data anti-tamper cost plan (if platform to be used in combat),
- Request a complete aircrew and vessel occupant PESHE (Programmatic Environment, Safety and Occupational Health) report,
- Request an Environmental Impact Assessment—if not covered in the standard PESHE report,
- Request a feasibility report for compliance with the *Information Assurance & Privacy Act*, and
- Request a Systems Engineering Management Plan.

a. Contract Competition & Type

FAR Part 6.102 mandates the use of competitive procedures in the pursuit of a commercial contract (GSA, 2005). Two competitive methods could be used for the Airborne RFID system: sealed bid or best value. For the initial procurement of

[57] Depending on the level of integration and/or interference between the Airborne RFID system and the airframe, the PMO or depot responsible for the airframe may become a prominent stakeholder. This may substantially increase costs, especially if aircraft airworthiness or safety certification is impacted.

the Airborne RFID system, we do not recommend sealed bidding due to the unknowns in the specific airframe that the system will integrate with. *World Class Contracting* states that, “to use sealed bidding, the buyer must have a specification that clearly and definitively describes the required product or service” (Garrett, 2007). Full and open completion will ensure the best technologies are presented to the acquiring agency. After the initial procurement of the system, and after successful fielding and implementation, subsequent procurements could be accomplished via the sealed bid approach for rapid resupply or expansion of the system footprint.

Best value procurement, as outlined in *FAR* 15.101, can be accomplished by open communication forums with industry, as outlined in *FAR* 15.201. “Exchanges of information among all interested parties, from the earliest identification of a requirement through receipt of proposals, are encouraged” (GSA, 2005, p. 343). We recommend hosting detailed discussions with RFID industry about this feasibility experiment and findings. Industry representatives will gain better understanding of the objective, limitations, and potential when presented with actual findings.

The uncertainties in dealing with the procuring agency’s unique airframe type are likely the only risk associated with using a firm fixed-price (FFP) contract. An FFP contract, as outlined in *FAR* 16.202, would ensure the suppliers quote the current (and often publicly known) COTS price for their RFID equipment. The acquiring agency could ask for proposal returns in weeks, rather than a month or more, which would accelerate the overall procurement timeline. Furthermore, according to *FAR* Part 12 for the acquisition of commercial items, “agencies shall use firm-fixed-price or fixed-price contracts with economic price adjustment” (GSA, 2005, p. 279). For the additional non-materiel items outlined above, the procuring agency could request flat-rate engineering man-hours to produce the information reports. Together, the cost of the RFID equipment and the man-hour requirements will qualify for the firm fixed-price construct.

A secondary option would be to pursue a fixed-price-incentive (FPI) contract. As outlined in *FAR* 16.204 and 16.401, the FPI can be written in a way that will establish a cost ceiling, but still allow room for cost growth if integration problems arise with the aircraft systems. Contractors can be incentivized by either speeding up delivery or producing solutions that out-perform the technical requirements. Depending on the type of aircraft the Airborne RFID system will be mounted on, and using the system price data outlined in this strategy, a fairly accurate target price can be calculated by the procuring agency, allowing little room for subsequent cost overruns during contract execution.

An FPI contract may have the disadvantage of being more paperwork-intensive and, thus, slower to process, but it may also have an advantage over the FFP if the agency's particular aircraft needs substantial levels of examination to integrate with the Airborne RFID system. After the contract type is chosen, the procuring office can use the sample Statement of Work (SOW) provided in Appendix B.

b. Post Solicitation

Jumping ahead to the point at which a contractor has been awarded the contract and is working on the solution, the procuring agency must be ready to supply any additional information about the specific airframe to the contractor engineers. The procuring agency should keep in mind that the technology does not have to be developed since the RFP specifically stated that current non-developmental items were required. With this understanding, it would not be unfair to ask for a product demonstration within a few weeks of contract award and to press the contractor for Preliminary Design Review (PDR) soon afterwards.

After the contractor has had access to the airframe and any airframe-related documents, the procuring agency should support any developmental test and evaluation measures necessary to prove the successful integration of the systems. Soon thereafter, the Critical Designs Review (CDR) should be held to assess technical progress, determine affordability results and lifecycle cost estimates, and ensure that the performance findings are well within the objective and threshold limits.

4. Production & Deployment Phase

This phase begins the mass production of the solution developed in the previous development stage. Initial low quantities will be delivered to the procuring agency for testing on the actual airframe, if not already accomplished. Depending on the perceived level of complexity for the interface(s) between the RFID equipment and the airframe, the procuring agency can enter either a Low-rate Initial Procurement (LRIP) phase for an extended amount of time or a Full-rate Production (FRP) phase, if initial LRIP items perform well in the fielded applications.

Production and deployment of the RFID tags are outside the scope of this appendix. However, the procuring agency must determine procedures for the acceptance of the RFID tags from the manufacturer. Once the tags become the property of the procuring agency and any warranties from the manufacturer are initiated, the procuring agency must have a plan in place to distribute the tags to the issuing agencies. Procuring the Airborne RFID system without a plan in place to distribute the tags is a waste of time and money since each component relies upon the other in order to function.

5. Operations & Support Phase

This final phase covers the utilization, support, maintenance, modernization, and disposal of the Airborne RFID system. Much about the exact requirements and activities in this phase is speculative; accordingly, we desire to point out only a few non-standard items that may be unique to the Airborne RFID system.

At the time of this feasibility study, the passive RFID tags (having no self-contained batteries) had a limited range of less than 100 feet. For obvious reasons, we ignored passive tags and studied only active tags, which carry their own power source and have been shown in this project to have ranges in the 3,000- to 5,000-foot range. The disadvantage with active tags is the price—the tags were $77 each, and typical passive tags can be priced as low as $0.20. As part of the Operations and Support phase, we recommend a periodic examination of the RFID market to see if technology maturation improves the passive tag's performance to a point at which they become viable options to the active-tag market.

Secondly, we recommend a constant examination of the operational environment to see if the Airborne RFID system could be interlaced with other information-gathering or disseminating programs or procedures. The output from the Airborne RFID system is a real-time snapshot of assets and their general location. Over time, each datum represents a piece of a puzzle that could be incorporated into behavior-mapping software programs or prediction analysis systems. For any program that requires such data, the Airborne RFID system should be introduced as a viable and fielded solution to minimize R&D costs for any new program.

Finally, for the foreseeable future, the active RFID tags require an internal battery for operation. Currently, these batteries have a shelf life of about ten years and an operational life of three years. To keep the Airborne RFID system operational, plans must be made and executed to replace the batteries before they reach the end of their designed life. In addition, the batteries must be disposed of in accordance to the environmental laws that govern the materials used in the batteries. The PESHE plan delivered by the contractor will outline many, if not all, of the avenues for proper disposal.

D. Summary

This strategy has been written as a start-up guide for a procuring agency that has been tasked with the procurement and initial implementation of an Airborne RFID system, similar to the one used in this feasibility experiment. Specifications of the equipment used in the experiment are coupled with the DoD's acquisition regulations to form a high-level manual for interested agencies. It must be noted that this guide cannot and must not replace official DoD and agency regulations and policies for acquisition and procurement.

Though many regulations and rules govern the procedures behind the procurement of an acquisition item, no one program can be acquired in exactly the same way that another program was acquired. Flexibility and creativity is often required to ensure the procuring agency receives the item(s) that it needs within the budget that it has.

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Appendix B. Sample Acquisition Statement of Work (SOW)

The contractor shall assemble an RFID system, consisting of pre-developed and tested items, for the purpose of use onboard a government aircraft. The RFID equipment must meet or exceed the size, weight, and performance specifications outlined in the equipment objective/threshold characteristics list found below. If these criteria cannot be met, please provide the procuring agency with rationale as to the reason. The equipment must not be developed specifically for this application, but must have been previously developed for use in other systems or applications and preferably have been qualified for industrial or military use.

The contractor shall examine airframe data provided by the procuring agency in order to propose a least-intrusive method for installing the RFID equipment and antenna onto the aircraft. Every opportunity must be taken by the contractor to minimize aircraft modification. Contractors who propose internally mounted antennas or the utilization of pre-existing aircraft antennas will receive higher consideration in the source-selection stage.

The contractor shall support a Preliminary Design Review and cursory equipment demonstration before the beginning of the fourth week after contract award. This accelerated timeline is requested in order to expedite the procurement process. Further, the contractor shall support a Critical Design Review four weeks after the completion of the airframe orientation, which will be set up by the procuring agency.

The contractor shall supply the procuring agency with detailed test and evaluation data of the proposed Airborne RFID system and will provide two systems, 50 tags, and two test engineers for government testing of the system.

In addition to the above deliverables, the contractor shall provide the following:

- An outline or specification for interface with the specific airframe on which the Airborne RFID system will be installed,
- Proposed airframe-specific mounting methods for the RFID antenna,
- Proposed airframe-specific antenna options—internal or external—and price/performance trade-offs,
- Proposed airframe-specific flight profiles for the best interrogation conditions,
- Proposed RFID system and aircraft electronic shielding techniques and subsequent navigation and instrumentation interference levels,
- Center-of-gravity correction calculations to account for additional weight,
- Expected aircraft performance impact(s) if equipment will be mounted in the airstream,
- Federal Communications Commission equipment certification of RFID equipment,
- An anti-tamper cost plan for data protection (if platform is to be used in combat zone),
- A complete aircrew and vessel occupant PESHE (Programmatic Environment, Safety and Occupational Health) report,
- An Environmental Impact Assessment—if not covered in the standard PESHE report,
- A feasibility report ensuring compliance with the *Information Assurance & Privacy Act*, and
- A Systems Engineering Management Plan.

Table 7. Equipment Objective/Threshold Characteristics List for SOW

	Threshold	Objective
Reader Size & Weight	2-3 lbs	Airframe Specific
Reader Frequency	433.92 MHz	433.92 MHz and other RFID tag frequencies that may potentially be used
Reader Environmental Limitations	Temperature: -32°C to +70°C Humidity: 100% Vibration & Shock: MIL-STS-810E Method 15.4, Category 10	Vessel or Organization Specific
Tag Size & Weight	Size: 6.25" x 2.125" x 1.125" Wt: 3.8 ounces	Vessel or Organization Specific
Tag Frequency and Power Output	433.92 MHz at 0.6 mW	Organization Specific
Tag Battery Life	10 Sec Beacon Mode: 1 Year Pole Mode: 3 Years	10 Sec Beacon Mode: 2 Years Pole Mode: 5 Years
Tag Beaconing Frequency	10 seconds to replicate experiment	<10 seconds for more readings per aircraft pass
Tag Environmental Limitations	Vibration & Shock: MIL-STD-810E, method 15.4, Category 10 Temperature: -32C to +70C Humidity: 100%	Airframe Specific

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Appendix C. Change Theory Applied to Fisheries

Of the stakeholders outlined in Chapter VI, the resource managers operate in perhaps the most complex environment with regard to implementation of a systemic change such as RFID monitoring of vessels. This appendix employs modern change theory to consider some of the issues related to RFID implementation in the resource-management environment.

A. New Regime

The new regime would be the implementation of RFID to supplement the Marine Recreational Fisheries Statistics Survey (MRFSS). This technology would be a complete shift from the way "business" is currently being conducted with respect to recreational fishers. There is currently very little oversight in the recreational fisher's community, with the exception of modest federal mandates and internal concepts (e.g., "no-take fishing"), and, as noted in Chapter II, the current MRFSS is inadequate in providing sufficient information to enable sound management decisions. By implementing RFID monitoring, better information would be brought to bear as a tool for resource managers to augment the data that is captured within the Marine Recreational Fisheries Statistical Survey.

Implementing RFID monitoring would also incorporate resource management into a developing infrastructure within the Federal Government[58] that would include a DMV-style registration system, on-site inspectors and enforcement personnel who would interface with the public.

One challenge arising from this would be the need to persuade recreational fishers that this move would have a positive impact on not only their sport but also on the overall health of the ecosystem.

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[58] As an integrated network which would include the Department of Homeland Security and the Department of Defense.

B. Explanatory Model for Resource Management

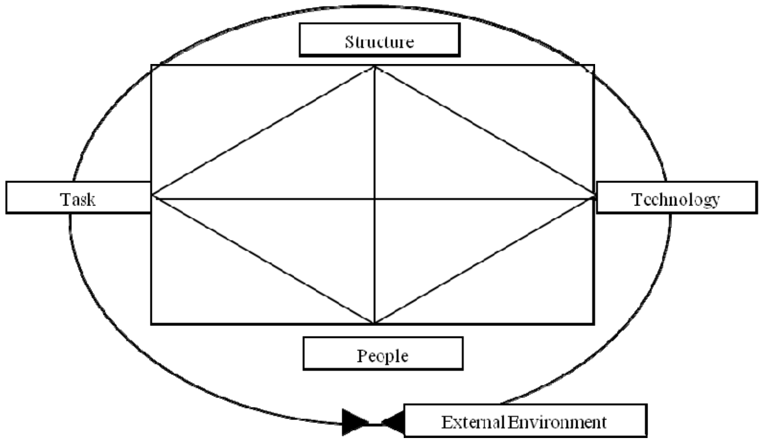

Figure 21. A Combination of Leavitt's Model with Weisbord's External Environment

1. Structure

The overall structure of marine fisheries management closely resembles a machine bureaucracy, though there are some ad hoc components within it. The primary agency that institutes policy among the marine fisheries within the United States is the National Oceanic and Atmospheric Administration (NOAA), which pushes the mandates and a majority of the enforcement responsibilities down to the lowest levels through state governments and their respective fish-and-game departments. Some state and local governments also institute policies that are more stringent than federal policies. Since the NOAA is a federal agency, there is a high degree of "publicness" that drives many of the policies set forth. That is, there are many stakeholders within and outside the government that wish to have their own agendas expressed through this agency and its policies.

If a problem were to arise for a given location, ecosystem, or species, the NOAA would institute measures to safeguard the resource. For instance, for the 2008 salmon fishing season, it was determined that the figures for the species abundance were below acceptable levels. Therefore, the NOAA closed salmon fishing in relatively short order, just prior to the start of the salmon fishing season.

2. Technology

The NOAA, through its various assets, is able to employ a multitude of advanced scientific methods, equipment, and resources to better manage the fisheries within the United States. However, most of the strategies employed are reactive. In other words, data will show that a particular resource has been overused in retrospect, and the resultant action that must be taken is more severe than if forecasting had been more prescient. There are very few assets deployed that provide data enabling the NOAA to be proactive, e.g., the NOAA's Tsunami DART® (Deep-Ocean Assessment and Reporting of Tsunami) buoys, which provide real-time information on benthic seismic activity. Currently, there is a movement within the Federal Government to institute a federal fishing-license database and a real-time small-vessel tracking (monitoring) system.[59] In short, several agencies within the Federal Government are asking that current and future technologies be developed and fielded to provide a substantial forecasting advantage to their required tasks.

3. People (Stakeholders)

Resistance to any form of monitoring is expected. Individuals or groups that desire not to have this technology would view this implementation as a potential invasion of privacy, an imposition or means to further gain tax dollars. Conversely, those who desire this technology may see this as a positive step forward, but not enough of a step forward. They may champion this technology and may expect more than can be offered by it. Or, they may simply desire to have this technology as a tool for resource management.

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[59] The small-vessel tracking system that has been proposed can act much like the Vessel Traffic System (VTS) for the larger vessels.

Stakeholders:

- Federal Government
  - Department of Commerce (DOC)
    - National Oceanic and Atmospheric Administration
      - Tasked with resource management and policy
  - Department of Homeland Security (DHS)
    - United States Coast Guard
      - Tasked with port security and enforcement within marine sanctuaries
  - Department of Defense (DoD)
    - United States Navy
      - Tasked with port security and concerns over vessel traffic around sensitive assets
- State Governments
    - Concerned with tax revenue and constituents' rights
  - Department of Fish and Wildlife (Game)
    - Tasked with endemic resource management and enforcement
- Local Governments
    - Concerned with local tax revenue and constituents' rights
  - Harbor Patrols and Sheriffs
    - Concerned with local vessel traffic and law enforcement
- Tribal Governments
  - Subsistence Fishers
    - Concerned that tribal rights and customs are honored and followed
- Environmentalist Groups
  - Concerned with health of the earth
  - Organizations ranging from pacifist to radical standpoints
    - Greenpeace

- Coast Watch
- Earth Liberation Front
- Earthwatch
- Conservation Foundation
- North American Native Fishes Association
- Cal Ocean
- Aquariums
- Colleges and Universities
- Et cetera

➢ Recreational Fishers
- Concerned about potential over-regulation
- Concerned with privacy issues
- Concerned that stewardship is being mishandled by the government
- Concerned with increasing taxes in volatile economy

➢ Resources
- Concerned with own population, recruitment and fecundity
- Concerned with invasive species
- Concerned with predator/prey cycles, i.e., trophic levels

➢ RFID Manufacturers
- Have viable stake in market

4. Task

The desired task is to implement a Radio Frequency Identification (RFID) program so that resource managers would have the ability to collect and analyze data for abundance and health management; security personnel would have the ability to inquire and interrogate vessel location and/or status in an unobtrusive manner, i.e., from a remote platform. The ultimate goal for this task is to have as much “buy-in” from as many of the stakeholders as possible because without support at the lowest levels, any well-intentioned program cannot succeed on its own merit.

5. External Environment

Burke states, “An organization’s history is also [an] input into the system” (Burke, 2008). This is an important concept to articulate in this particular instance. Resource management has long been a controversial subject that has had a tumultuous relationship with the general public. Prior to the establishment of resource-management statutes, it was often the individual(s) utilizing the resource that acted as steward(s) of the resource—an example of the public caring for the commons. However, as populations began to expand, the commons were at risk for over-exploitation to satisfy singular or multiple uses, e.g., over-fishing a certain species to satisfy current market demand. As a result, the Federal Government stepped in and began regulating resource consumption. This was met with both disdain and hope.

The hope was that the Federal Government would be able act in the best interest of all. However, as many have pointed out, the Federal Government’s agenda is constantly changing as successive administrations influence policy. Thus, resource management has become an amalgamation of the goals of several different administrations and has been seen by some members of the public as a puppet of corrupt politicians. As an example, former Alaska Senator Ted Stevens was an instrumental force in creating and passing one of the most effective pieces of marine-resource legislation, the *Magnuson-Stevens Fishery Conservation and Management Act*. However, he was later denigrated, and subsequently lost his Senate seat, for his alleged role in several corruption scandals, including the infamous “Bridge to No Where.”

Ultimately, all sides of the marine-resource issue can find fault in either too much, not enough, or ineffective regulation and call selective opinions into question when it suits their respective need.

C. Plan for Implementation

The primary model that would be used for implementation would be Lippitt's Phase of Planned Change and how the ideas of unfreezing, establishing a change agent, moving, refreezing and termination can demonstrate RFID technology as a tool that can benefit everyone (Warner, 2008, p.144). Lippitt's model, coupled with Vroom and Lawler's Expectancy Theory (Miner, 2005, p. 96), provide a good resource to create a baseline for proposed change within the NOAA's methodology.

1. Phases of Planned Change

a. Unfreezing

The NOAA has been made aware that there are flaws within their data, data collection, and data analysis that have a direct impact on marine resource management. The National Research Council (NRC) was commissioned by the NOAA to conduct an in-depth analysis on its Marine Recreational Fishery Statistics Survey (MRFSS). The NRC published its findings not in a paper, but in a book. The NRC illustrated in its book that a key component in the MRFSS is flawed: the concept that recreational fishers are only taking a trivial amount from the ocean and need not be concerned when conducting diversity and abundance studies.

Some estimates put the total take of some species up to 80% by recreational fishers and 20% by the commercial industry (NRC, 2006). While it can be argued that commercial fishers appear to take large hauls relative to the average weekend fisher, the cumulative effect that the recreational fishers are having is more profound (King, 1995). Thus, the NOAA has come to the realization that they need to capture better data about the marine recreational fisher. The NOAA needs to augment, supplement or completely reorganize the Marine Recreational Fishery Statistic Survey.

b. Establishing a Change Agent

Establishing a change agent for this proposed change would be the most important step. By looking at the various stakeholders, one can see that these groups are extremely passionate on both the pro and con sides of the argument. The individual or group that would proffer the change would need to understand the various regional issues that are specific to each group of stakeholders. For example:

- Fishermen are going to know which species they want to catch;
- Environmentalists may want to protect that same species for intrinsic values, or because they believe that the species may be a vital link in trophic levels that other species are dependent upon for survival;
- Universities may want to explore this species because it may provide answers to other questions within the system, or because they believe that this species needs to be protected for future use or studies;
- Local governments may want to exploit that species because it brings in tourism dollars in the form of fishing or “eco-tourism”; and
- State or Federal Governments may have placed that species on a watch list and are directed through federal regulation to maintain and add to the current levels.
- Another prospective wrinkle may take the form of which agency would lead the charge. If more than one agency decided that it wanted to control the technology for its own purposes, then there would be a potential for a control struggle between the agencies attempting the same goal—tracking small vessels—but for different purposes.

c. Moving

Once the technology has been cleared for use, it would begin to assimilate itself into the boater’s community through different forms of campaigns, as in the following: 1) new vessels would be constructed with this technology already embedded into the hull construction; 2) current vessels would need to register their vessels with a federal database and receive and install their transponders; and 3) if vessels were to be taken out of the database (destroyed, no longer sea worthy, dry docked for an indefinite period, etc.), then a reclamation process to recover the technology would be required. The NOAA would have to install their own infrastructure to handle the technology.

d. Refreezing

After the initial hurdle of fielding this technology has been accomplished, the maintenance and upkeep of the technology would be relatively simple. The infrastructure, as a result of emerging studies and theories, would be in a somewhat constant state of internal flux. Maintaining the appeal of this technology would also be an issue, and it may have to move accordingly with the current state of the stakeholders. That is, the current political climate may put an emphasis on a particular individual, group or species that may draw immediate attention and require a shift.

e. Termination

The entire evolution from concept to full fielding could be on the order of years. Therefore, the termination would happen as an overlap when the culture of fishers is such that this technology begins to become "natural" and no longer an imposition.

<u>Potential Timeline</u>

- April 2010: Beta Test for feasibility study on current technology
- May 2010: Feasibility test on current state of technology[60]
- October 2010: Publish findings on feasibility study[61]

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[60] Another feasibility test may be required to further "fine tune" current technology.

61 After publishing the findings, presentations to the NOAA, DHS and DoD will need to happen.

- November 2010: Acquire funding for pilot study
- January 2011: Initiate pilot studies and begin to acquire feel for current stakeholders in larger regions
- March 2011: Hold “town hall” meetings in various regions to address stakeholders
- July 2011: Approach vessel manufacturers about integration into hull designs on new models, and integration into older models
- August 2011: Address current state of IT infrastructure
- January 2012: Publish findings from pilot study
- February 2012: Hold more “town hall” meetings in various regions
- March 2012: Initiate small-scale fielding to marine sanctuaries
- December 2012: Assess effectiveness of small-scale fielding
- January 2013: Hold “town hall” meetings to inform about full-scale implementation
- April 2013: Full-scale implantation[62]
- May 2013: Assess effectiveness of full-scale implementation on MRFSS
- January 2015: Transponder batteries would need be replaced[63]

2. Expectancy Theory

a. Unfreezing

If the fishers “buy in” (this group of stakeholders should provide the most resistance), then there is the ability to show them that with their assistance, better data could be collected. Thus, better recommendations could be made as to which

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62 This may be dependent on regional fishing seasons.

[63] This date is based on a 2-year battery life. Expect technology to allow for longer battery life or easier integration while maintaining 2-year threshold.

species of fauna[64] to regulate instead of blanket no-catch regulations (closing of certain fishing seasons). Therefore, their behavior can be shown as directly proportional to the enjoyment of their fishing experience in terms of catch and money.

b. Refreezing

Once the technology has proven beneficial to the fishers, the rewards for them would become more self-evident as stocks begin to reach their carrying capacities and limits are lifted.

D. Data

The target demographic would be the recreational boaters, primarily the recreational fishers. The data collected would be mostly qualitative. However, using inferential statistics, information could be quantified with respect to type of fishing, amount of fishing, location of fishing, length of fishing, and profession.

a. Sample Survey Questions

1. What types of fishing do you participate in? (Circle one):
   Recreational, Subsistence, Both

2. Are you able to make a living with your fishing? (Circle one):
   Yes/No

3. How many days per year do you fish? ____________

4. Where do you typically fish when you stay locally?
   Specific Location: ___________________________

[64] Fauna means carbon-based organisms other than plants. Here, this entails fish, abalone, octopi and any other regulated species currently targeted by fishers.

5. When you travel outside of your local area, where do you typically go?
   Specific Location: ___________________________

6. During a typical fishing trip, how many hours do you fish?
   Hours: _________________

7. What is your given profession?
   ____

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