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Cost-benefit analysis of implementing an aluminum and tin recycling program onboard United States Naval Combatants

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COST-BENEFIT ANALYSIS OF IMPLEMENTING AN ALUMINUM AND TIN RECYCLING PROGRAM ONBOARD UNITED STATES NAVAL COMBATANTS

by

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December, 1995

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This thesis analyzes the financial feasibility of implementing a recycling program onboard U.S. Naval Combatants. Numerous laws and international agreements provide the impetus for the Navy to make drastic changes in its solid waste management practices. This study focuses primarily on revenues generated from the sale of aluminum and tin, as they compose the most significant portions of a ship's recyclable waste stream. Specific factors investigated include storage limitations, sanitation concerns, manpower issues, cost constraints, lack of training, lack of incentives, tangible benefits, and perceived benefits. Research was conducted onboard four classes of U.S. Naval Combatants: Arleigh Burke Class Destroyers, Oliver Hazard Perry Class Frigates, Spruance Class Destroyers, and Ticonderoga Class Cruisers. Usage data for both tin and aluminum were gathered from each ship type to determine required storage volumes and potential revenues from the sale of the recyclables. A thorough space inspection was conducted of each ship type to ascertain potential storage spaces and their suitability for temporary storage while underway. Specific findings are that there is adequate storage room aboard these ships, that crews' quality of life will not be sacrificed, and that there exists potential for significant revenues by selling the recyclable cans, all of which are retained by the ship. More generally, it is shown that it is cost-effective to implement an aluminum and tin recycling program onboard U.S. Naval Combatants.

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ABSTRACT

This thesis analyzes the financial feasibility of implementing a recycling program onboard U.S. Naval Combatants. Numerous laws and international agreements provide the impetus for the Navy to make drastic changes in its solid waste management practices. This study focuses primarily on revenues generated from the sale of aluminum and tin, as they compose the most significant portions of a ship's recyclable waste stream. Specific factors investigated include storage limitations, sanitation concerns, manpower issues, cost constraints, lack of training, lack of incentives, tangible benefits, and perceived benefits. Research was conducted onboard four classes of U.S. Naval Combatants: Arleigh Burke Class Destroyers, Oliver Hazard Perry Class Frigates, Spruance Class Destroyers, and Ticonderoga Class Cruisers. Usage data for both tin and aluminum were gathered from each ship type to determine required storage volumes and potential revenues from the sale of the recyclables. A thorough space inspection was conducted of each ship type to ascertain potential storage spaces and their suitability for temporary storage while underway. Specific findings are that there is adequate storage room aboard these ships, that crews' quality of life will not be sacrificed, and that there exists potential for significant revenues by selling the recyclable cans, all of which are retained by the ship. More generally, it is shown that it is cost-

effective to implement an aluminum and tin recycling program onboard U.S. Naval Combatants.

TABLE OF CONTENTS

LIST OF TABLES

I. INTRODUCTION

This thesis analyzes the financial feasibility of implementing a recycling program onboard U. S. Navy ships. It focuses primarily on revenues generated from aluminum and tin, since they compose the most significant portions of a ship's overall waste streams.

A. BACKGROUND

The United States Navy had for centuries been dumping all of its garbage over-the-side. This had been a commonly accepted practice, primarily because the technology and incentives did not exist to retain the wastes onboard. It has only been a few decades in which environmental consciousness about the oceans has arisen as a matter of public concern. Recent international environmental agreements supported by our own public laws began to radically change the way the Navy views its environmental responsibilities. These new public pressures and laws to be "kinder to the environment" have forced the Navy to develop new programs to deal with garbage disposal at-sea.

Senator Sam Nunn addressed the growth of environmental issues in a speech on the Senate floor in 1990. His concerns centered around the issue of environmental issues posing a new threat to U.S. National Security. He commented:

> I am persuaded that there is also a new and different threat to our National Security emerging in the destruction of our environment. The defense establishment has a clear stake in countering this growing threat. I believe that one of our key National Security objectives must be to reverse the

accelerating pace of environmental destruction around the globe [Ref.1:p.7].

Currently, only a few programs require ship Commanding Officers to restrict what is disposed over-the-side. These programs generally apply to plastics, sewage, petroleum products, and hazardous wastes when ships are operating in close proximity to land or cruising for fewer than three days. With the exception of plastic wastes, Commanding Officers are permitted to dump over-the-side any quantity and type of trash they deem appropriate. This stands to reason because there aren't any mandated programs to retain and/or recycle any other components of the waste stream.

As national and international pressures increase to improve the environment, regulations on ocean dumping are continuing to grow more restrictive. Environmentalism, national defense, and politics are rapidly becoming inextricably intertwined. In his January 1994, State of the Union Address, President Clinton stated:

> As we protect our environment, we must invest in the environmental technologies of the future which created jobs. And of course, there are still dangers in the world...severe environmental degradation the world over...as the world's greatest power, we must therefore maintain our defense and our responsibilities...We worked to promote environmental sustainable economic growth [Ref.2:p.7].

In order to comply with recent laws (to be discussed in Chapter II), Congress has mandated that the Navy reduce its waste streams dumped overboard to zero by December 31, 1998 [Ref.3:p.2]. After that date, nothing is to be dumped over-the-side unless certain extraordinary circumstances exist or permission is granted by a higher authority.

Now is the time to investigate the technologies and programs necessary to meet the

1998 deadline. Recycling aluminum and tin is one certain way to reduce the overboard waste stream and earn additional revenues for the ship. Numerous Department of Defense (DoD) organizations and contractors are working on developing emerging technologies to achieve "zero discharge" by 1998. Some of the current projects include compactors, incinerators, pulpers, shredders, vacuum sealed trash enclosures, plasma arc thermal destruction, and many more. Rather than examining these emerging technologies, this thesis focuses on programs that can be implemented immediately to reduce the waste stream and earn the ship some money simultaneously.

B. OBJECTIVES OF RESEARCH

Because most ships discard significant portions or all of their aluminum and tin waste, this research will focus on the financial feasibility of implementing a recycling program for these two materials onboard U.S. Navy ships. Specifically, the primary research question is: "Is it cost effective to recycle aluminum and tin onboard U.S. Naval ships?" Subsidiary research questions include: How do the following factors affect the implementation of an aluminum and tin recycling program onboard Naval ships, either positively or negatively?

a. Storage limitations

b. Sanitation concerns

c. Manpower issues

d. Cost constraints

e. Lack of formal recycling and environmental awareness training

f. Lack of incentives for implementing aluminum and tin recycling programs

g. Tangible benefits (increased ship's revenues, increased efficiency of aluminum and tin resources, lower cost of operations, improved environment by dumping less into the oceans)

h. Perceived and intangible benefits (helping save the environment, good public relations for Navy, pride in improving efficiencies and lowering costs)

C. SCOPE AND ASSUMPTIONS

1. Scope

There are many items onboard Navy Ships which are recyclable. However, this research will focus specifically on aluminum and tin due to their predictable consumption levels while both inport and underway, as well as their commercial recyclable values. For the purpose of this thesis, "tin" will refer to the cans which are used to store food for the galley. These cans are actually classified in recycling markets as ferrous steel, but are commonly referred to as "tin cans".

Time considerations also require that this thesis focus specifically on four types of combatants: the Ticonderoga Class Aegis Cruiser, Arleigh Burke Aegis Destroyer, Oliver Hazard Perry Class Frigate, and Spruance Class Destroyer. Exploiting many commonalities among all U.S. Navy ship types, statistical models and proportional analysis will be used to extrapolate the data to draw conclusions and recommendations for other types of Navy ships. Specific ships researched were: USS PRINCETON (CG-59), USS JOHN S. MCCAIN (DDG-56), USS OLDENDORF (DD-972), USS DAVID R. RAY (DD-971), USS REID (FFG-30), and USS SIDES (FFG-14).

2. Assumptions

Several assumptions are made throughout this thesis, as outlined below:

1) A ship's consumption level of aluminum and tin can be accurately estimated on a per person/per day basis.

2) No aluminum or tin is destroyed once onboard.

3) Two basic consumption levels for a particular ship, inport or underway.

4) 100 percent recovery rate of aluminum and tin once a recycling plan has been implemented.

5) Potential revenues from recycling based on adequate storage facilities and conformance to Naval Supply Systems Command (NAVSUP) and Navy Occupational Safety and Health (NAVOSH) sanitation requirements.

D. METHODOLOGY

In addressing an aluminum and tin recycling program on Navy ships, this research focuses on three primary sources of information: observation, archival, and opinion.

1. Observation

The initial strategy consists of directly observing shipboard methods for handling, storing, and disposing of wastes inport and at-sea. This type of analysis is very accurate and represents reality. The primary weakness of observational analysis is that it makes no reference to the past. Another is that you're limited to what you can observe in the time available.

2. Archival

The second strategy uses archival data. It will provide much of the concrete evidence needed to support the conclusions. The archival data will consist mainly of the ship supply records and logs. These documents will indicate quantities and types of goods brought onboard the ship, as well as quantities consumed. Since almost nothing is brought back ashore, it will be relatively simple to determine the approximate amount of aluminum and tin dumped overboard in a given time period. The archival data provides the tools necessary to extrapolate past trends into future predictions. It will be a critical part of the analysis because it will establish a "baseline recycling goal" for each ship type.

3. Opinion

The third research methodology is opinion data. It will be obtained through interviews of the Commanding Officers, Executive Officers, Supply Officers, and members of the ship's crew of each ship visited. It will be used to establish current attitudes and beliefs regarding shipboard waste disposal control systems currently operating and proposed recycling programs. It will also help estimate resistance to, or limitations of, the establishment of recycling programs onboard Navy vessels. The opinion data will be obtained using standard questions to ensure uniformity and help eliminate potential biases. The results will be inferred to include much larger populations.

On the down side, the data is purely subjective. It is very difficult to detect personal biases and it can often be inaccurate due to many dynamic conditions (e.g., person is having a "bad day" or an incentive to misrepresent the truth). The methodology has considered these potential problems and tried to minimize bias.

E. ORGANIZATION OF THE STUDY

1. Chapter I: Introduction

Chapter one describes the rationale for conducting this research and provides a brief overview of why it is important to devote time and effort into recycling onboard Navy ships. The research question is defined, as well as the limitations and methodology.

2. Chapter II: Environmental Legislation

Chapter II begins with a description of environmental legislation which is driving the Navy towards "zero discharge" from its ships. This "zero discharge" has been mandated by Congress to occur not later than December 31, 1998. Legislation discussed includes the Act to Prevent Pollution from Ships (APPS) 1980, 1987 and 1994 Amendments to APPS, National Environmental Policy Act (NEPA) 1970, Pubic Law 103-160 (1993), and the Pollution Prevention Act (1990).

Navy programs to comply with environmental legislation are also discussed. Examined in particular are the Plastics Removal In the Marine Environment (PRIME) and the formation of the Solid Waste Executive Steering Committee by the Under Secretary of the Navy in 1994. Penalties for willful environmental violations by U.S. governmental employees are delineated.

3. Chapter III: Analysis of Need/Demand

The need for the Navy to comply with established environmental laws and potentially future more stringent requirements is discussed. The need for additional revenues, a cleaner environment, compliance with public law, positive public relations, and the desire to do the "right thing" will be covered. The requirement for Navy compliance with environmental legislation and actions of "environmental stewardship" is being imposed by Congress and the Department of the Navy (DoN) itself.

4. Chapter IV: Implementing an Aluminum and Tin Recycling Program Onboard Naval Combatants

The factors which must be considered before deciding whether or not to implement a recycling program onboard Navy ships will be examined in Chapter IV. A typical ship's waste stream will be analyzed to determine quantities of materials suitable for recycling. Sanitation requirements and storage limitations will be discussed, as well as the Odor Barrier Bags (OBB). The identification and establishment of a Central Recyclables Collection (CRC) space is addressed, as well as its particular location, equipment, and inspection requirements. Finally, manpower issues are examined.

5. Chapter V: Data Presentation and Analysis

This chapter begins with a discussion on data gathering strategies. It then delineates the assumptions made in performing the calculations. The historical records data as well as the empirical data and observations gathered during ship visits are presented and then analyzed and extrapolated to determine the cost-effectiveness of implementing an aluminum and tin recycling program. Direct and indirect costs associated with implementing the recycling program will be compared with the benefits derived from such activities. Tangible and intangible benefits will also be included in the analysis. Finally, opinion data will be presented and discussed.

6. Chapter VI: Conclusions and Recommendations

An overall summary of the data and cost-benefit analysis will provide the necessary information to support conclusions regarding the feasibility of recycling aluminum and tin onboard Navy ships. Recommendations will be based upon the information and arguments presented in previous chapters. It will provide clear and concise guidance, supported with evidence, for Navy policy in this area.

Recommendations will also be presented for possible ways to divert revenues from recycling to each ship's operating account. A shift in fiduciary policy allowing a CO to transfer recycling revenues to an appropriated account could, in the long run, serve to reduce the necessary appropriated funding without jeopardizing mission readiness..

F. SUMMARY

Commanding Officers of today's Navy ships, especially combatants with little or no excess storage space, are faced with difficult decisions regarding solid waste management. For many CO's, time and manpower constraints prohibit them from accurately weighing the costs and benefits of implementing an aluminum and tin recycling program onboard their ships. With the information provided in this thesis, they will be able to make informed decisions as to whether or not a recycling program on their ship is worth the effort.

Recycling will also generate additional costs including storing, sanitation concerns, and manpower constraints, but if a recycling program is initiated onboard their ship, the benefits will also be manifold. The ship will increase its revenues by selling the recyclables (proceeds currently being allocated directly to the ship's MWR fund), improve public relations, and improve the ocean environment by reducing waste being dumped in it.

II. ENVIRONMENTAL LEGISLATION

The movement towards "zero discharge" of wastes from Navy ships has been mandated by law to occur by 31 December 1998. Numerous laws and international agreements provide the impetus for the Navy to make drastic changes in its solid waste management practices. Currently, there are at least sixty different federal statutes governing military environmental actions [Ref.4:p.11]. With few exceptions, the Navy must adopt new methods and technologies to reduce its ocean dumping to comply with these new and more demanding requirements.

A. ACT TO PREVENT POLLUTION FROM SHIPS (APPS)

1. Background

In 1973, the United States and other maritime nations signed a treaty known as the International Convention for the Prevention of Pollution from Ships [Ref.5:p.6]. It regulated the discharge from ships of garbage and other solid wastes. It was modified in 1978, and acquired the acronym MARPOL 73/78 or MARPOL Protocol (Maritime Pollution) [Ref.6:p.7] There are five annexes to MARPOL 73/78, the most significant of which for the U.S. Navy is Annex V, Regulations for the Prevention of Pollution by Garbage from Ships. Annex V prohibited the discharge of paper, cardboard, metal, glass, and plastic near land and in "special areas."

To implement the treaty, Congress passed the Act to Prevent Pollution from Ships (APPS) on 21 October 1980 [Ref.5:p.2]. APPS was the first environmental legislation in many years affecting the Navy. It suggested that ships minimize the materials dumped into the ocean when practicable. Since it had no "real" enforcement mechanisms, the Navy did not modify or change its Standard Operating Procedures (SOP) regarding shipboard waste disposal.

APPS did have a few significant impacts within and outside the Department of the Navy (DON). For the Navy, it served as a "warning bell" that environmental legislation and requirements would become increasingly prevalent and more stringent. Outside the DON, the act signaled that environmental concerns were beginning to influence the decisions of our elected politicians.

2. 1987 Amendment to APPS

APPS was amended in 1987 to implement Annex V of the MARPOL Protocol. It was implemented with the passing of Public Law 100-220, "Marine Plastic Pollution Research and Control Act (MPPRCA) of 1987" [Ref.6:p.7]. American legislators did not feel that the MARPOL agreement went far enough to protect the oceans and included the following in the 1987 Amendment: 1) No plastics discharge; 2) Other solid waste discharges banned in "special areas" designated by MARPOL; and 3) U.S. Navy compliance by 31 December 1993 [Ref.7:p.4]. This new legislation was the first which truly forced the Navy to adhere to very stringent ocean dumping regulations.

The 1987 Amendment presented the Navy an extremely difficult challenge. First, six years was not much time to change how the Navy had been handling its wastes for hundreds of years. Also, significant R&D was needed to identify mechanical and other non-industrial processes to help minimize a ship's waste stream. Studies would need to be conducted and evaluated, followed by source selection, eventually leading to a contract for equipment. If not commercially available, time for production was needed, as well as ship trials and suitability testing. To summarize, a very aggressive installation program was needed to comply with the 1993 deadline.

The Navy failed to meet the 1993 deadline, and requested an extension of five years from Congress. As efforts were undertaken to reduce the waste stream (covered later in this chapter), the Navy was still experimenting with various devices to retain the wastes onboard as long as possible.

3. 1994 Amendment To APPS

The Act to Prevent Pollution from Ships (APPS) was again amended by Congress in the FY 94 Department of Defense Authorization Act [Ref.7:p.5]. It basically granted a six year extension for the Navy to fully comply with APPS. It took into account the Navy's current RDT&E status and current shipboard tests of various systems.

Specifics of the FY 94 DoD Authorization Act are:

(1) Plastics Processors must be installed on Navy ships by 31 December 1998, and 2008 for Submarines.

(2) Other solid waste discharges (except food) in MARPOL-designated "special areas" must stop completely by 31 Dec 2000 (Surface ships), and 2008 (Submarines).

(3) By November 1996, the Navy must provide Congress a list of ships for which compliance is not technically feasible and proposed alternative schedules.

(4) Congress may modify APPS requirements "as appropriate" after

reviewing the Navy's plans (e.g., some ships, such as Coastal Patrol Crafts or Minesweepers, may not be physically capable of retaining wastes onboard.

(5) Navy will immediately implement 3/20 day plastic retention policy for ships not currently equipped with Plastic Processors (retain non-food contaminated plastics for at least the last 20 days prior to returning to port, and retain food contaminated plastics at least the last three days before returning to port).

(6) Navy will record and periodically report on all Navy discharges into MARPOL-designated "special areas" [Ref.7:p.4].

4. "Special Areas" Currently in Effect

Five MARPOL designated "special areas" are currently in effect. These "in effect" areas are classified into two categories, one for garbage wastes and one for oily wastes. The "in effect" areas for garbage are the Baltic Sea, North Sea, and Antarctic Area. For oily wastes, they are the Mediterranean Sea, Baltic Sea, Black Sea, and the Antarctic Area [Ref.8:p.1].

B. NATIONAL ENVIRONMENTAL POLICY ACT (NEPA)

1. Background

On May 29, 1969, Executive Order 11472 was signed by President Richard Nixon. It was designed to bring federal agencies into compliance with federal environmental regulations. It established the Citizens Advisory Committee on Environmental Quality and the Environmental Quality Council. These two councils produced a series of recommendations used in drafting of legislation known as the National Environmental Policy Act (NEPA) [Ref.9:p.11]. NEPA became law January 1, 1970 [Ref.10:p.1].

NEPA was a national charter for protecting the environment. It established new environmental policy, set goals, and required decision-makers to analyze environmental impacts of proposed actions before final decisions or actions are taken. NEPA mandated "that all Federal Agencies utilize a systematic, interdisciplinary approach that will ensure the integrated use of the natural and social sciences and the environmental design arts in planning and decision-making, which may have an impact on man's environment." [Ref.10:p.2]. To summarize, it created a basic outline for governmental agencies to become more environmentally conscious and take steps to help improve the environment. One of NEPA's other goals was the promotion of our society's growth without sacrificing our future by destroying our environment.

NEPA had two basic tenets:

(1) Procedures must be in place to ensure environmental information is available to decision-makers and citizens before final decisions are made and major federal actions are undertaken.

(2) The NEPA process should identify and assess reasonable alternatives to proposed actions to avoid or minimize adverse environmental effects [Ref.10:p.6].

These tenets brought the Navy's environmental programs into full public disclosure. At the same time, NEPA also created the Council for Environmental Quality (CEQ) which has provided the regulations to implement the procedural provisions of NEPA [Ref.11:p.5-1]. The CEQ uses three basic tools to accomplish its mission. The tools are Categorical Exclusions (CE's), Environmental Assessments (EA's), and Environmental Impact Statements

(EIS's). These are templates used to classify, assess, and report environmental impacts of various federal agency programs and procedures.

a. Categorical Exclusions (CE's)

Categorical Exclusions are actions that do not have, under normal circumstances, individually or cumulatively, a significant effect on the human environment. They may also have been previously found to have no negative effects as a result of procedures adopted by the Navy for implementing CEQ regulations [Ref.10:p.3]. These exclusions provide the Navy a procedure to determine if its standard operating procedures were harmful to the environment and require corrective or abatement actions. This resulted in many Navy internal studies, as well as a significant number of independent investigations.

b. Environmental Assessments (EA's)

EA's provide a uniform method of reporting the current status of an environmental program or situation. They provide the reporting format which includes, at a minimum, the following:

(1) A description of sufficient evidence criteria for determining whether to prepare a Environmental Impact Statement (EIS).

(2) A description of sufficient evidence criteria for determining whether to prepare a Finding Of No Significant Impact (FONSI).

(3) Guidelines for preparing the EIS when one is necessary through the use of standard forms and procedures [Ref.10:p.6].

c. Environmental Impact Statement (EIS)

The EIS provides a uniform method for estimating the potential negative impact of a particular action or practice and identifying possible "environmentally friendly or neutral" alternatives. It is a tool which is required whenever there is a possibility that an action by a government agency could harm the environment. The EIS is a "full and unbiased" discussion of significant environmental impacts and informs decision-makers and the public of the reasonable alternatives that would avoid or minimize adverse effects on the human environment" [Ref.10:p.6]. A negative EIS cannot stop a project from starting, but it can severely postpone it until a subsequent positive EIS is presented.

2. Compliance with NEPA

The Navy is committed to conforming to the NEPA mandates. There are many minor implications of complying with NEPA besides Categorical Exclusions, Environmental Assessments, and Environmental Impact Statements. The Navy's responsibilities in complying with NEPA can be summarized as follows:

a. Navy representatives must assess environmental consequences of proposed actions that could affect the quality of the environment in the United States, its territories, and possessions per DoD and CEQ regulations.

b. The Navy must ensure that presently unmeasured environmental amenities are considered in the decision-making process.

c. The Navy must consider reasonable alternatives to recommended actions in any proposal that would involve unresolved conflicts concerning alternative uses of available resources.

d. The Navy must make available to States, Counties, Municipalities, Institutions, and individuals advice and information useful in restoring, maintaining, and enhancing the quality of the environment.

e. The Navy must use ecological information in planning and developing resource-oriented projects [Ref.10:p.5].

C. OTHER PUBLIC LAWS MANDATING NAVY ENVIRONMENTAL REGULATION AND COMPLIANCE

1. Public Law 103-160, Div A, Title X, Section 1003

Public Law 103-160 (PL-103) is yet another driving force behind the Navy's attempts to be kinder to the environment. It establishes a set of dates by which the Navy must install the Plastic Waste Processors (PWP) onboard its ships. It was enacted for several reasons. First, it put pressure directly on the Secretary of the Navy (SECNAV) to ensure that its aggressive installation schedule was feasible and completed on time. It also took into consideration the Navy's extensive RDT&E efforts and successful testing of the Plastic Waste Processors onboard a few trial ships. Lastly, the procurement and installation times required to outfit all Navy ships were integrated into the schedule.

The law specifically promulgated the following schedule:

"- NLT July 1, 1996 Secretary of the Navy must install the first production unit of the Plastic Waste Processor.

- NLT March 1, 1997: 25% of all ships owned or operated by the Navy will be equipped with a Plastics Processor.

- NLT July 1, 1997: 50% of Navy ships will be equipped with a Plastics Processor.

- NLT July 1, 1998: 75% of Navy ships will be equipped with a Plastics Processor.

- NLT Dec 31, 1998: 100% of Navy ships will be equipped with a Plastics. Processor"[Ref.12:p.2]

2. Pollution Prevention Act of 1990 (PPA)

This act was proposed by the Environmental Protection Agency and enacted by Congress to combat pollution through a source reduction program. Source reduction involves examining all the components of each organization's production processes, seeking ways to improve efficiencies, using more environmentally friendly materials, recycling or reusing previously discarded scrap, etc. This act caused the Navy to identify methods to reduce the amount of materials onloaded to ships that were not essential and eventually were discarded overboard. The Act provided for training programs and established an award system for significant source reductions and pollution prevention innovations [Ref.13:p.4].

As a result of this Act, the DoN has responded by allocating significant resources towards pollution prevention over the past several years. For example, the Navy spent 104 and 121 million dollars for pollution prevention in Fiscal Years 93 and 94 respectively [Ref.14:p.1].

D. NAVY PROGRAMS TO COMPLY WITH ENVIRONMENTAL LEGISLATION

1. Background

The U.S. Navy has several ongoing environmental protection and compliance research projects. Described below are a few current major initiatives.

a. Plastics Removal In The Marine Environment (PRIME)

The purpose of PRIME is to reduce the plastics used on Navy ships. It was a response to PL-100-220, which bans the worldwide discharge of plastics into the oceans [Ref.12:p.26]. It was originally championed by Naval Supply Command (NAVSUP), but management was transferred to Ships Parts Control Center (SPCC) in December 1994 [Ref.15:p.1]. Its efforts will directly reduce the amount of plastics dumped into the oceans until Dec 31, 1998, when all plastic waste processors are to have been installed and "zero"plastic discharges are permitted.

As of 1993, PRIME, in association with the Defense Logistics Agency (DLA), has reduced or eliminated plastic packaging from 400,000 items with an estimated reduction of over 650,000 pounds of plastic brought aboard U.S. Navy ships per year [Ref.15:p.2]. This was primarily accomplished by product substitution and minimizing plastic packaging and packing materials.

2. Oversight And Independent Analysis

a. Solid Waste Steering Committee

The Navy has contracted numerous studies on environmental impacts of ocean dumping over the past several decades. In May 1994, Under Secretary of the Navy Richard Danzig established a Solid Waste Executive Steering Committee to oversee the Navy's research initiatives and compliance with environmental legislation. The Committee is chaired by the Deputy Assistant Secretary of the Navy for Environmental Security, Ms. Elsie Munsell [Ref.7:p.3]. This committee will provide Congress its findings by November 1996, complying with the deadline stipulated in the 1994 amendment to APPS.

b. Primary Independent Analysis Organizations

Although the Navy has contracted many organizations to conduct research in this area, most research and independent analysis of environmental impacts of waste management on Navy ships is conducted by two institutions; the National Academy of Sciences Naval Studies Board and the Center for Naval Analyses. The primary focus of the National Academy of Sciences Naval Studies Board has been technical solutions. The Center for Naval Analyses (CNA) has been concentrating their efforts on waste retention and retrograde solutions [Ref.7:p.3].

c. Public Meetings

The Navy holds public meetings to solicit input from various contractors and concerned citizens. It is a forum in which the public has an opportunity to participate in the Navy's development of their solid waste management program. The most recent public meeting was held at the Navy's Carderock Laboratory on 20 September 1994. It was hosted by the Solid Waste Steering Committee, led by Ms. Elsie Munsell, Deputy Assistant Secretary of the Navy (Environment and Safety). Over 100 persons attended, including many from other public agencies, private corporations, environmental groups, and university researchers [Ref.15:p.8].

E. PENALTIES FOR ENVIRONMENTAL VIOLATIONS

1. Background

For centuries, the United States government and its employees have enjoyed a unique sovereignty when they violated the laws of our government. Individuals were basically immune to personal prosecution, as the courts focused their attention on the federal agency, rather than the individual. This tendency to overlook the individual and blame the "system or organization" had a negative effect in providing an incentive for federal employees to break the law without fear of reprisal. Environmentally, this led to many practices which severely degraded our environment.

2. Current Personal Liability Legislation

The days of immunity for federal employees for violations of anti-pollution laws are gone. Individuals are being held personally liable for their actions, as well as leaders of the organizations for whom they work. This change of personal accountability is reflected in a statement by Cheryl A. Kandaras, Principal Deputy Assistant Secretary of the Navy (Installations and Environment), before the Subcommittee on Defense of the Senate Appropriations Committee on DoD Environmental Programs, May 17, 1994.

> Because we need continued use of and access to these lands, our seas, and the airspace over them, we view our environmental programs as an integral part of our overall management effort to accomplish our mission. We hold the Commanding Officer responsible and accountable for compliance with all environmental statutes and regulations. We provide this person with the funding, training opportunities, and other support functions necessary to enable full compliance with environmental standards, as well as mission accomplishment [Ref.16:p.2].

This new emphasis on environmental compliance has placed a great burden of responsibility on Commanding Officers. Under current federal laws, a ship's violation of an environmental statute is a felony offense for the Commanding Officer [Ref.17:p.3]. An excerpt from OPNAVINST 5090.1A reads:

> Most environmental statutes impose criminal liability for willful or knowing violations. Some statutes impose criminal liability for negligent violations. Service members may also be subject to trial by court-martial or to nonjudicial punishment for violation of environmental laws and regulations. Violations

may also be prosecuted in state or Federal courts [Ref.11:p.1-5].

3. Impacts of Liability Legislation

a. Fines and Imprisonment

Since federal agencies and their employees are now liable for violations of environmental laws, there is a potential for significant fines and reduction in operational readiness for the Navy. Violating one of the environmental laws can mean thousands, even millions, of dollars in fines for the Navy and place the base or ship's Commanding Officer in jail. In FY-93, the Defense Department faced nearly nine million dollars in fines stemming from several instances of non-compliance with environmental laws [Ref.18:p.8].

b. Operational Readiness Issues

It is possible that if the Navy cannot comply with environmental legislation, its operations can be reduced or suspended by a judge for failure to comply. In 1994, Rear Admiral J. Scott Walker was in charge of nearly 3,000 sailors and civilians whose full-time job to clean up, recycle, study, or otherwise conserve the environment. He commented: "If we fail to comply with the laws and regulations, the operational and readiness impact can be absolutely devastating...We can be forced to cease operations" [Ref.18:p.8].

F. SUMMARY

The Navy is facing some very serious challenges in the next several years stemming from recently enacted environmental legislation. The FY 94 Amendment to the Act to Prevent Pollution from Ships (APPS), the National Environmental Policy Act (NEPA), Pollution Prevention Act of 1990 (PPA), and other laws are driving the Navy towards "zero discharge" by 31 December 1998.

The Navy is conducting large-scale research and development projects, reducing non-essential packaging materials from the supply system, and is soliciting assistance from both the private and public sector. Compliance with all environmental laws is the Navy's goal, as non-compliance carries significant penalties and the possibility of serious reduction in operational readiness.

III. ANALYSIS OF NEED/DEMAND

In order for recycling onboard Naval Combatants to be feasible, it must satisfy both a need and/or demand for its existence. It must comply with applicable laws and regulations as well as satisfying a particular deficiency in our standard operating procedures. This chapter will focus on the entities which need and/or would benefit from recycling aluminum and tin onboard Naval Combatants and those which have a demand for implementing the program.

A. THE NEED

The need for an aluminum and tin recycling program onboard Naval Combatants is based upon several factors. First and foremost, the Navy must comply with environmental legislation. Second, the DoN is pursuing methods of reducing the impact that its dumping has on the ocean environment. Finally, the Navy is committed to ensuring combat readiness while striving to conserve energy, promote an image of being a "caretaker of the environment," and earn revenues to increase its efficiency. This is supported by a statement from the Navy's Environmental and Natural Resources Program Manual which states;

> All Navy activities shall implement source separation for recycling and develop a single Qualified Recycling Program (QRP). Materials for which proceeds can be obtained shall be sold through the host activity's QRP. A QRP shall be established for the following purposes: 1) To comply with federal, state, and local environmental laws and regulations; 2) To obtain proceeds for the sale of recycled materials; 3) To avoid excessive costs for disposal of solid waste by other means; 4) To reduce the volume of wastes disposed in landfills; and 5) To reuse readily available resources [Ref.11:p.10-6].

The establishment of an aluminum and tin recycling program will assist the Navy in meeting these ends.

1. Compliance with Laws and International Agreements

As delineated in Chapter II, there are many laws and international agreements which have restricted the Navy's ability to dump trash into the oceans. They have, as a whole, established a strict set of rules which alter the methods by which the Navy disposes of its wastes as opposed to dumping everything off the fantail. With each successive year, the dumping regulations have become more restrictive and have caused the Navy to develop new and innovative compliance procedures.

Whether to comply with environmental regulations is not an issue for top naval leadership. The question is, how to comply, given current operational requirements and waste management technologies. The Navy has always attempted to comply with environmental regulations to the best of its ability, but technological and space/sanitation requirements have hindered total compliance. The recycling of aluminum and tin onboard Naval Combatants solves a portion of the Navy's problem on what to do with the wastes that cannot be comminuted and discharged overboard after 31 December 1998.

2. Reduce Negative Environmental Impact

The United States Navy has for centuries been dumping its wastes over-the-side, regardless of the environmental impact. With environmental awareness growing at an astounding rate, the Navy needs to reduce its ocean dumping both because it is the "right thing to do" and it complies with the law. In this respect, eliminating aluminum and tin dumping into the oceans is certainly a value added activity.

a. Floating Marine Debris

Floating marine debris is an eyesore, a hazard to mariners, and may be dangerous to marine sea life. Floating marine debris can be found washed ashore on any beach around the world. The problem is not that the debris is toxic, but that aluminum and tin are relatively stable in the marine environment and can take hundreds of years to biodegrade [Ref.3:p.i]. It certainly has an aesthetic impact which decreases the quality of life of those persons inhabiting the coastlines. For beach goers, the debris poses a danger in the water and on the beach. Bathers and people walking the beach have been injured, some severely, from accidental contact with debris either washed onto the beach or floating closely offshore. Additionally, beach debris may pose a health hazard, and invariably causes high news media interest [Ref.3:p.3]. If the trash is somehow connected to a Navy ship (not infeasible), the bad publicity would be detrimental to the public image of the Navy.

For mariners, floating debris poses a variety of problems. If large enough, it could puncture the hulls of watercraft or create significant damage. Most commonly, however, the floating debris causes entanglement problems with the ship's propellers, possibly disabling the ship. Other problems have occurred when debris has been ingested into the engine cooling water intake systems, disrupting or disabling its function. These problems can pose significant hazards to navigation.

The most alarming victims of floating debris are sea life. Often times, they mistake the debris for other forms of sea life and ingest it or become entangled and drown. The following statistics help clarify the immensity of the problem:

- In 1984, The National Academy of Sciences estimated that ocean sources dumped 14 billion pounds of garbage into the sea every year-more than 1.5 million pounds per hour.
- Along 300 miles of Texas coastline, more than 15,600 six-pack plastic rings and tons of other garbage that washed ashore were found in just a three hour search.
- More than 100,000 marine mammals and one million sea birds die each year from floating debris, primarily from ingestion and entanglement [Ref.3:p.C3].

3. Promote Positive Navy Public Image

Since we are public servants, it is in the Navy's vested interest to promote an image as "caretakers of the environment." The Assistant Secretary of the Navy for Installations and Environment was recently quoted as follows:

> Natural resources conservation is a vital component of our nation's environmental agenda. Our continued mission access to domestic airspace, land, and coastal waters is dependent on public confidence that we are competent and conscientious stewards of resources entrusted to our use. We must earn this confidence installation by installation, and on an operation by operation basis [Ref.16:p.2].

The recycling of aluminum and tin onboard Naval Combatants can play a vital part in the Navy's efforts to ensure the public's confidence that we are upholding their environmental policies. The program would demonstrate a commitment to seeking methods to reduce overboard discharges, with an added benefit of possibly reducing the ship's dependence on appropriated funding (supported by data analysis in Chapter V).

4. Potential Revenues Obtained from Recycling

One of the primary benefits of recycling aluminum and tin is the potential for generating significant revenues. The revenues obtained by recycling activities onboard Navy ships are governed by BUPERSINST 1710.11B. There is no ceiling on the amount of proceeds that a particular command can generate; however, there are certain restrictions on what the revenue can be used for.

At a minimum, fifty percent of the proceeds from a recycling program must be distributed to the local MWR department supporting military MWR activities [Ref.19:p.6]. The individual ship's Commanding Officer has the option to keep the revenues from the sale of recyclables for the ship's MWR fund, or allocate it to the local Naval Station MWR fund. As evidenced by interviews with ship Commanding and Executive Officers, nearly all choose to keep the money for onboard MWR use.

5. Ensure Readiness

One of the primary missions of the United States Navy is to be prepared to conduct combat operations at sea in support of our government's policies. Accomplishing the mission and destroying the environment do not have to be synonymous. This idea is embodied in a statement taken from the Department of the Navy 1995 Natural Resources Conservation Strategic Plan. It reads;

> The mission of the United States Navy is first and foremost...to support the requirements of the Unified Commanders so that our nation can deter aggression, encourage political stability, provide forward presence, establish sea control, and project power from the sea against any threat and win. Implicit in this mission is a responsibility to deter aggression and encourage political stability at home by working to achieve ecologically sustainable development at home and abroad. Our national security is inextricably linked to local, regional, and global ecological integrity [Ref.16:p.3].

6. Energy Conservation

Recycling aluminum and tin will help conserve vast amounts of energy and resources.

Recycling will save the resources and energy required to mine and process the raw materials used in producing aluminum and tin. It will also decrease the overall amount of pollutants (air and waterborne) in our environment as the by-products of the refining and production processes.

Aluminum is one hundred percent recyclable and it is twenty percent cheaper and requires only five percent of the energy to recycle as opposed to original production from virgin raw materials [Ref.20:p.102]. For tin, the story is similar. Tin cans are also one hundred percent recyclable and require only a fraction of the original energy and materials to recycle and remanufacture [Ref.20:p.105].

B. THE DEMAND

There are numerous entities which have a legitimate requirement for supporting an aluminum and tin recycling program on Naval Combatants. The major stakeholders are Congress, the Department of the Navy itself, and the American public. Each possesses a different perspective, but arrives at the same conclusion: implement a recycling program.

1. Congress

Congress has oversight authority for the United States Navy, as delineated in the Constitution. This power is exercised in many ways, but one that is particularly relevant to this discussion is control over budgetary authority. The Navy has a vested interest in keeping a good relationship with Congress because it is dependent on annual congressional appropriations. Congress's interest in defense environmental programs is evident in the fact that "Although defense spending has declined roughly 15 percent since 1990, funding for environmental security programs has increased over 290 percent" [Ref.21:p.77].

2. Department of the Navy

The DoN must attempt to do more with less. Any increases in efficiencies which can be obtained without sacrificing operational readiness are worthy of investigation. The DoN is also concerned with preserving our environment and protecting the oceans. This commitment to simultaneous environmental preservation as caretakers of our natural resources and continued military readiness as defenders of our country is evident in the mission statement of the Deputy Under Secretary of Defense for Environmental Security (DUSD(ES)):

> DoD's Environmental Security Program fulfills four overriding and interconnected goals. First, comply with the law. Second, support military readiness of the U.S. Armed Forces by ensuring continued access to the air, land, and water needed for training and testing. Third, improve the quality of life for military personnel and their families by protecting them from environmental, safety, and health hazards. Fourth, contribute to weapons systems that have improved performance, lower cost, and better environmental characteristics [Ref.22:p.6].

a. 1995 DoN Spending

This commitment is evident through the money the DoN has allocated to comply with environmental legislation. In FY-95, the Navy spent over 1.5 billion dollars on environmental programs. The money was allocated as delineated in table 1:

Department of the Navy FY 95 Funding of Environmental Programs	
Compliance	$ 800 million
Cleanup	$ 400 million
Conservation	$ 20 million
Pollution Prevention	$ 140 million
RDT&E	$ 26 million
Environmental Technologies	$ 72 million
Environmental Protection	$ 44 million
Environmental Quality and Advanced Logistics Technology	$ 21 million

[Ref.14:p.36]

Table 1

b. Projected Total Program Funding Requirements

The estimated funding resources required to execute the shipboard solid waste equipment installation program (installing plastic processors, metal shredders, and pulpers onboard nearly every ship) through Fiscal Year 1999 are summarized below. The quantity and variety of the equipment installed will vary by each ship type, depending on ship size, storage room, etc. All costs are projected for the out years by NAVCOMPT:

Future Projected Funding for Shipboard Solid Waste Disposal Equipment Installation	
Fiscal Year 1995	$ 134.3 million
Fiscal Year 1996	$ 289.7 million
Fiscal Year 1997	$ 334.0 million
Fiscal Year 1998	$ 56.2 million
Fiscal Year 1999	$ 18.8 million
TOTAL	**$ 833.0 million**

[Ref.23:p.47]

Table 2

Funding in the later years (FY 98-99) is dramatically less because most of the ship installations of environmental equipment will be completed. Revenues generated from the sales of these recyclables could help Commanding Officers maintain operational readiness with a source of funds not appropriated by Congress.

3. American Public

The demand for the federal government, specifically the DoN, to become more environmentally friendly is ultimately driven by the American public's insistence on change. As evidenced by the tremendous quantities of environmental legislation passed in the last two decades, the public is demanding that the Navy reduce wastes being dumped into the ocean. The recycling of aluminum and tin can drastically reduce the waste stream, while increasing the ship's efficiency by generating some revenues.

IV. IMPLEMENTING AN ALUMINUM AND TIN RECYCLING PROGRAM ONBOARD U.S. NAVAL COMBATANTS

What are the factors which must be considered in deciding whether or not to implement an aluminum and/or tin recycling program onboard Naval Combatants? What are the inherent risks, and possible ways to minimize those risks? Where will the cans be stored and can they be crushed to reduce their volume? Can each combatant support the program given already stringent demands on their crews? Will the health and safety of the crew be jeopardized? Will operational effectiveness and combat readiness suffer?

The goal of this thesis is to address these and other concerns. Implementing a recycling program is a big commitment for a ship's Captain and crew, and all pros and cons must be carefully considered before undertaking such a program. There are many obstacles which could deter CO's from implementing a recycling program, but careful analysis proves it is feasible and practicable. Additionally, OPNAVINST 5090.1B, 1 November 1994, requires establishing recycling programs to avoid costs, to reduce the volume of materials landfilled, and to obtain proceeds from recycling [Ref.11:p.10-6].

A. WASTE STREAM IDENTIFICATION

1. Background

Before analyzing what items will be recycled as part of this program, the major components of the ship's waste stream must first be identified. Once sorted into major components, those items that are aluminum and tin items (both of which are recyclable) will be identified and segregated from the balance of the remaining waste stream.

2. Shipboard Waste Stream Generation Rates

Based upon numerous research studies sponsored by the DoN, it is possible to estimate, with a relatively high degree of accuracy, the amount of waste generated on each ship per day. The common denominator used in this estimation is the number of personnel stationed onboard each ship. The main variable affecting the quantity of wastes generated was based on whether the ship was underway or inport, as underway periods generated significantly more wastes than inport periods [Ref:3:p.ii]. The calculations for this thesis will include a proportional average of both inport and underway figures.

Two studies on solid waste generation rates were conducted by the Navy in 1971 and 1988. The results were as follows:

Waste Type	1971 Quantities (lb/person/day)	(%)	1988 Quantities (lb/person/day)	(%)
Paper	1.03	(34%)	1.11	(35%)
Food	1.33	(43%)	1.28	(41%)
Plastic	.01	(0.3%)	.21	(7%)
Other	.68	(22%)	.55	(17%)
TOTAL	**3.05 lb/person/day**		**3.15 lb/person/day**	

[Ref.3:p.ii]

Table 3

3. Component Analysis of Shipboard Generated Wastes

Included in the "other" waste category are the primary items addressed in this research. "Other" waste includes glass, aluminum, steel, wood, white paper, cardboard, and a few others. In samples collected from shipboard generated wastes between January 27 and February 7, 1992, the following components were identified and quantified based on weight:

Components of Shipboard Generated Wastes

Type of Waste Material	Waste Stream Percentage
Metals	10.71% 22.70% of 10.71% is aluminum cans 48.65% of 10.71% is ferrous cans
Glass	1.68%
Inorganic	7.49%
Cardboard	21.01%
Paper	18.23%
Plastics	9.84%
Organic	31.01%

[Ref.24:p.28].

Table 4

4. Sources of Aluminum and Tin

The single largest source of aluminum waste onboard is soda cans from the ship's vending machines. As such, they are the only source used in these calculations. They also comprise 2.44 percent by weight and 4.00 percent by volume of the ship's entire waste stream [Ref.24:p.34]. Tin cans from the galley comprise an estimated 98 percent of all steel waste generated on the ship.[1] This represents 5.22 percent of the ship's total waste stream by weight and 3.00 percent by volume [Ref.24:p.34].

5. Aluminum

The aluminum cans dispensed by the soda machines are a standard twelve ounces. They are composed of 100 percent aluminum and are completely recyclable. They measure 4.75 inches high and 2.50 inches in diameter, and weigh .039 pounds (empty weight). They are very malleable and are easily crushed using several different methods. Some common methods to crush aluminum cans are:

- Using a "wide head" (min 3" diameter) rubber mallet
- Using a wall-mounted can crusher (hand operated)
- Stepping on can with shoe and applying sufficient pressure (dangerous)
- Crush with bare hands (dangerous)

6. Tin (Steel)

Tins cans used most frequently onboard navy ships are from the galley. There are a few other miscellaneous sources of steel onboard (mainly from the Engineering Department, specifically the Repair Division), but the quantities are relatively insignificant and infrequent. They will not be factored into the calculations in Chapter V. Tin cans are not very malleable and cannot be easily crushed without the assistance of an electric or hydraulic crusher. The cans are comprised of four basic sizes, which are classified as follows.

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[1]"Tin can" is a misnomer in the context used here, but it is commonly used to refer to the cans in which a majority of the ship's food is stored. Tin actually refers to the tin lining on the inside of the cans, although due to its high price, many manufacturers are switching to other metals or plastic liners. For this thesis, the term "tin cans" will be used vice ferrous steel cans.

Common Tin Can Sizes Used Onboard Navy Ships

Can Type	Height (inches)	Diameter (inches)	Weight (pounds)
# 10 can	7.00 in	6.00 in	.606 lbs
# 2 1/2 can	4.63 in	4.00 in	.231 lbs
# 3 cylinder	7.05 in	4.25 in	.328 lbs
# 300 can	3.75 in	2.00 in	.026 lbs

Table 5

B. SANITATION REQUIREMENTS

1. Background

One characteristic which separates United States Navy ships from many other ships around the world is their unquestionable dedication to sanitation and cleanliness. Onboard every U.S. Navy ship, the Executive Officer's (XO) Inspection of Messing and Berthing is a daily ritual. It is a very thorough inspection of the ship's sanitation intended to ensure a high quality of life for our sailors and a healthy place to eat, work, and live.

The idea of storing empty cans onboard for extended time periods presents several health and sanitation concerns. These concerns are addressed in Naval Supply Systems Command Instruction (NAVSUPINST) 4061.11G, which clearly delineates rules and regulations regarding food and food wastes onboard U.S. Navy ships.

2. Regulations

One of the primary regulations found in NAVSUPINST 4061.11G states that no wastes may be stored in or around the ship's reefers or dry storage areas. Additionally, food-contaminated containers must be removed from the galley at the most expeditious time after they have been opened. If the containers remain onboard for an extended period of time, then they need to be washed in soapy water and rinsed in hot water to kill the bacteria. This washing and rinsing is conducted in the scullery.

3. Bacterial Growth and Insect Infestation

Another concern is bacterial growth and subsequent insect infestation. In order to prevent this, storage space will need to be completely washed after each recyclables off-load, including bulkheads and storage containers. After thorough cleaning, the space will need to be disinfected with general purpose spray (GP). Following thorough disinfecting, the space should be sprayed with an insecticide to kill any parasites that may have survived the cleaning and disinfecting. These steps collectively are referred to as sanitizing.

The above mentioned procedures need to be conducted on a regular basis. At the minimum, every time that the can storage space is emptied it must be completely sanitized. The sanitization need not be conducted for the entire space, if conditions do not permit. Portions can be completed at a time, with the cans being moved periodically to expose previously covered sections.

4. Odor Barrier Bag (OBB)

a. Background

A significant concept in improving food-contaminated waste storage sanitation onboard ships is the Odor Barrier Bag (OBB). The OBB was developed by Naval Surface Warfare Center, Carderock Division (NSWCCD) Annapolis Detachment. It has been thoroughly tested and was approved for fleet use in April 1995 [Ref.25:p.2]. The OBB system was designed for long term storage of food contaminated garbage onboard ships.

b. OBB Components

The OBB system has three primary components: the bag, the heat sealer, and a vacuum pump. Once the wastes are inside the bag, the vacuum draws out excess entrapped air to decrease the overall bag size. The vacuum procedure takes slightly longer than sealing the bags without a vacuum, but the vacuum sealed bags reduce the overall storage volume by 45 percent [Ref.25:p.2].

The bags are available in two sizes, large and small. The large OBB measures 36x50 inches, and the small OBB measures 24x27 inches. The bags and heat sealers are available via the Navy Supply System, with the vacuum being commercially available. Detailed instructions and guidance about the OBB system are available in NSTM Chapter 593, currently under revision.

c. OBB Physical Requirements

When the OBB system was in the early developmental stages, the engineers at NSWCCD were tasked with determining the minimum specifications for satisfactory bags. The following five requirements were generated and used as design characteristics. The bags must:

1. Have low aroma and gas permeability properties.
2. Be processed easily using existing bag-making manufacturing equipment and technologies.
3. Be transparent.
4. Have high tensile strength properties
5. Have high tear strength properties.

6. Be resistant to wide variations in humidity and temperatures. [Ref.26:p.3].

C. STORAGE LIMITATIONS

1. Background

One of the primary and most obvious problems with implementing a recycling program onboard Naval Combatants is storage space. Chapter V addresses each combatant ship type specifically, with recommendations on what particular spaces to use for waste storage. This chapter examines the problem of limited storage availability and discusses ways to successfully handle the challenge this presents.

Aluminum and tin can storage must be handled in an organized and efficient manner. There are several ways to organize and store the cans and additional resources and equipment, if any, that are required. Topics such as can segregation, distributed or centralized storage, and accessability are critical to choosing an appropriate location.

2. Can Segregation

Can segregation is a critical function which must be performed at the soonest practicable time after the can has been "consumed." For tin, a separate container should be located in the galley near the sink area to permit the cans to be rinsed before discarding them into the proper container. For aluminum, locating containers throughout the ship in high soda consumption areas is ideal.

a. Tin

A separate container in the galley for tin cans provides temporary storage and has several benefits. First, it prevents duplication by sorting the trash only once. Second, it keeps the cans from further food contamination once they have been rinsed. This "source segregation" is an efficient method of collection and provides an ideal method of transferring it to the permanent storage location until it is transferred off the ship.

b. Aluminum

The aluminum cans should also be source segregated. Since they are consumed throughout the ship, there should be numerous locations for crew members to conveniently discard their cans separate from normal garbage. Each workcenter and berthing compartment should contain separate containers for aluminum cans..

3. Distributed vs Centralized Collection

Due to the limited amount of storage spaces available on the ship, it would seem logical to have one Central Recycling Collection (CRC) space. When a particular temporary bin is full, a crewmember could then deposit it in the CRC. It is easy, efficient, and not very manpower intensive on a workcenter level.

a. Aluminum

Aluminum cans can be found in nearly every inhabited space on the ship. They can be easily crushed "on-station" by a variety of different means, preferably a wall-mounted, hand-operated crusher. Aluminum soda cans are not prone to spoiling shortly after being opened, and therefore can be held in each individual workcenter or berthing compartment for days at a time before having to be moved to the CRC. Once a workspace's aluminum storage container is full, it should then be deposited at the CRC. For some workcenters/workspaces, it is possible to store the crushed cans in sealed plastic bags for extended periods of time.

For aluminum, a distributed collection system would be optimum. The CRC could be used then as a last resort in order to save space for tin cans and attempting to keep the size of the CRC to a minimum.

b. Tin (steel)

Tin cans are found primarily in the galley and are normally food-contaminated (contained some liquid-based product which begins to spoil within a few hours after opening.) To clean the cans of all bacteria would require putting them through the dishwasher. This is clearly impractical and too manpower intensive. There is also no room in the galley to store empty cans for more than two meals, in addition to being a health violation. Finally, there is no room in the galley to install a can crusher.

Tin cans should be rinsed with hot soapy water in the scullery to remove most food particles to control bacteria growth and limit spoilage. Once rinsed, they should be taken directly to the CRC for compacting and storage. Centralized storage for food contaminated tin cans is the only viable solution.

4. Central Recycling Collection (CRC) Space Requirements

a. CRC Space Characteristics

The CRC should be a space with adequate room to store the crushed cans and not endanger anyone working in the space from falling stored cans. It must have adequate to excellent ventilation to keep the air from growing stale or noxious. It does not require any additional fire protection equipment, in that the cans are totally non-combustible. A drain directly overboard would assist in cleaning, but is not a requirement. Minimizing sharp and protruding objects in the storage area decreases the probability of puncturing the Odor Barrier Bags.

b. CRC Space Location

The space should be easily accessible to any crewmember and located in close proximity to the galley to minimize the distance that food-contaminated wastes are carried around the ship. It should also be situated in a convenient area near the skin of the ship. The objective is to shorten the length of the route from CRC to the ship's weatherdecks to minimize the possibility of spreading food-contaminated wastes along the path. The location should be approved by the Damage Control Assistant (DCA) and the Safety Officer, with the CO/XO's concurrence.

c. CRC Space Equipment

(1) Shelving/Racks/Bins. The CRC does not require any special shelving or racks to store the cans once they are crushed. Each ship can devise their own method of actually storing the cans. On the USS SIDES (FFG-14), the crew stores food-contaminated plastic waste in a 400 gallon plastic tub located in their starboard helicopter hanger. They highly recommend it because it contains any leaks or spills, and is easy to clean. A smaller version for an internal CRC would be an asset.

(2) Compacting and Sealing Equipment. The CRC should contain an hydraulic or electric tin can crusher. The hydraulic crushers can be hand operated or electrically powered. Both are effective, although the hand operated crusher is much less

expensive, easier to use and maintain, and requires less space.

Another item which should be collocated in the CRC is the Odor Barrier Bag System (OBB). The OBB system includes a roll of OBB's, a heat sealer, and the vacuum pump. The crushed cans can be placed in the OBB for extended storage periods. In order not to puncture the OBB, care must be taken when loading and handling each bag. If consistent puncture problems are occurring, the crushed cans can be placed in a burlap or cloth sack or paper bag before placing them in the OBB.

d. CRC Space Inspections

The CRC needs to be inspected at a minimum of once per day. The risks of bacterial growth, insect infestation, unsafe, and generally unhealthy conditions are extremely high if proper attention to cleanliness and sanitation is not observed. It is critical to be proactive in this regard because once problems arise, they are very difficult to bring under control.

It is recommended that the CRC should be inspected by the following personnel on the schedule annotated below.

Recommended CRC Inspection Schedule

Title or Position	Inspection Interval
Executive Officer	Daily
Environmental Officer	Daily
Food Service Officer or Leading Mess Management Specialist Chief Petty Officer	2X per day
Mess Decks Master at Arms	4X per day following each meal cleanup
Senior Medical Department Representative	weekly
Occupational Safety & Health Official	yearly

Table 6

The inspections should be recorded on an inspection sheet posted on the CRC entrance hatch. The inspection sheet should contain blank columns for the inspector to note the following information:

- Name of inspector
- Date and time of inspection
- Results of inspection (Satisfactory or Unsatisfactory)
- If unsatisfactory, was appropriate person notified to correct discrepancy
- Comment section for inspector to list specifics
- Signature block

After each inspection, the inspector should sign and date the inspection sheet.

e. CRC Space Responsibility

Overall responsibility for the CRC space should rest with the Environmental Officer (EO). He/she should maintain all paperwork and records associated with its operation. As the CRC space on most combatants does not already exist, it will have to be approved by the CO and designated in writing as such. The EO should maintain this Letter of Designation creating the CRC. The CRC space inspection forms should be replaced weekly by the EO, and the originals held as official records for a period of six months. The EO should also oversee CRC space maintenance. The EO and Senior Medical Department Representative (SMDR) should both keep a record of all fumigations and any other preventative or corrective actions.

D. MANPOWER CONSIDERATIONS

1. Background

As with any new program implemented onboard Navy ships, one of the first questions is, how much labor will it require, and how long will it take to complete each day? In today's shrinking Navy, Commanding Officers are having to learn to do more with less. Very rarely, if ever, are ships fully manned during normal operating cycles. The highest manning levels are usually reached just before a ship leaves for deployment; the lowest manning levels are generally immediately following deployments. To compound the problem, Reserve ships are consistently severely undermanned.

2. Manpower Estimations by Work Breakdown Structure

The aluminum and tin recycling plan must limit its impact on the crew in order to be successful across the board. It must not create a management nightmare nor require significant supervisory attention. It should clearly contribute to the habitability of the ship and not cause inconvenience or excessive amounts of additional work. To more accurately estimate the impact on the crew, the various parts of the problem will be examined individually.

a. *Segregation*

(1) Aluminum. Since aluminum cans are consumed throughout the ship, segregating cans from regular trash should be relatively simple. Each workspace and berthing compartment should have a separate container in which to store used aluminum cans. Portable wall-mounted hand-operated can crushers would facilitate the process.

These actions do not place an undue burden on the workcenter or berthing compartment personnel. The aluminum collection receptacle and temporary storage are conveniently located in the space where they work/live. Overall estimated manpower impact is minimal.

(2) Tin (Steel). Since the majority of tin is generated in the galley, source segregation is the optimum solution. Separate containers to collect the tin cans should be located in the galley for convenient use by the Mess Specialists (MS's). At the conclusion of each meal, the cans should be rinsed in soapy water to remove food particles in the scullery. Once rinsed, they should be transported to CRC to be crushed. These steps require

additional work by either the MS's or someone appointed by the Mess Decks Master at Arms (MDMAA). Overall estimated manpower impact is moderate.

b. Storage

(1) Aluminum. Once per day, the individual workspace supervisors should empty the crushed cans into a plastic bag and seal the top with a twist tie. Each workspace retains the cans in their respective space until it becomes an undue burden or jeopardizes operational/combat readiness. When required, workspace personnel can transport the cans to CRC for permanent storage. Overall estimated manpower impact is minimal..

(2) Tin (Steel). After every meal, the cans must be cleaned and transported to the CRC to be crushed. At the conclusion of each day, crushed cans must be placed into an OBB and sealed. This requires moderate effort. Using learning curve theory, it can probably be accomplished very quickly with experience. Overall estimated manpower impact is minimal.

c. Collection/Maintenance

Aluminum cans will be collected and temporarily stored in each individual workspace; tin cans are collected and deposited in the CRC after every meal. Once the cans have been bagged and stacked, not much else is required until transfer. The primary job which must be accomplished on a daily basis is cleaning.

Daily cleaning includes cleaning the floors, ensuring that the stacks of the OBBs are securely stowed for sea, and general housekeeping tasks. This should take one person no more than 15 minutes per day, providing there are no major problems. A major "field day" of the space should be conducted every time the cans are off-loaded and the space emptied. If the OBBs were not punctured during storage, the amount of cleaning will be relatively minor and take only a few minutes to accomplish. Overall estimated manpower impact is minimal.

d. *Off-Ship Transfer of Recyclables*

(1) Inport (home port). While inport, the recyclables should be transferred off-ship at least once per day. This will completely empty the CRC and make it available for thorough cleaning and fumigation. For convenience, each ship should have two temporary storage containers on the pier (one for aluminum, one for tin) to collect recyclables until a sufficient quantity exists to transport to the local recycling facility.

When the pier container is full, a ship's vehicle and personnel will transfer the cans to a local recycling facility for reimbursement. A contractor could also be hired to perform this function. Approximate costs for a contractor to transport the recyclables to a local recycling facility is $32/ton, which includes the cost of the machine and operator [Ref.27:p.15]. Once deposited at the recycling facility, a check will be issued and the funds will be deposited directly into the ship's MWR account. Overall, the transfer process is manpower intensive, but is infrequent and for short durations.

e. *At-Sea*

During underway periods, a ship has three basic alternatives: retain recyclables onboard until return to homeport, transfer recyclables to Combat Logistics Force (CLF) ships, or retain onboard and transfer at an other-than-home port. Each option has several advantages and disadvantages which must be considered prior to taking any action.

(1) Retain Onboard Until Homeport. If possible, this is the best option for the Commanding Officer for several reasons. First, the ship will maintain personal custody of the recyclables and be able to liquidate them into cash upon arrival inport. This is the easiest and least management intensive option because no further arrangements have to be coordinated before the recyclables are off-loaded.

(2) Transfer Recyclables to CLF Ships. This is also a viable option for a ship's CO. It will allow the ship to remain more operationally ready. The ship can remain underway for a longer time if it has more space to store additional ship-generated wastes. A few examples of CLF ships include Supply Ships, Tenders, Ammunition Ships, and Oilers. The two most common methods of transfer while at-sea are:

- Vertical Replenishment (VERTREP) with helicopters
- Highline transfer during Underway Replenishment (UNREP)

One of the primary drawbacks of these two methods is that the two ships must remain alongside each other for extended periods of time during an UNREP, or must remain in close proximity during VERTREP operations. The process is also management intensive because the CLF ship will take custody of an asset, which must be signed-for and subsequently tracked by the originating ship. Follow-up by the originating ship will be required to ensure that the revenues generated from selling the recyclables are returned to the ship.

The originating ship's CO can transfer custody and all rights to the recyclables after they have been off loaded from his/her ship to the CLF Commanding Officer.

If this option is exercised, the originating CO will forfeit any and all revenues that the CLF ship generates from selling those recyclables.

(3) Transfer at Other-Than-Home Port. While deployed, this might often be the only option available to a ship's CO. Coordination via Logistics Requirements message (LOGREQ) will be required to arrange for off-load. The LOGREQ should inquire if there are any recycling centers in close proximity to the pier or anchorage, and if they would be amenable to picking them up directly from the ship. If the nearby recycling center will not pick up the materials from the ship, the CO must inquire about the availability and price of a truck for ship's personnel to transport recyclables to the recycling center. If the potential benefits (revenues) from the sale of the recyclables does not exceed the cost of the vehicle, further analysis needs to be conducted.

The additional price to dispose of the cans with the regular waste stream needs to be compared with the price of the rental truck and potential revenues from sale of the cans. With these two figures, a decision can be made on how best to dispose of the cans. The overall manpower requirements for other-than-home port transfer of recyclables will vary depending on the situation and are difficult to estimate.

f. Accounting

The accounting aspects of establishing and maintaining an aluminum and tin recycling program are relatively simple. The ship's Disbursing Officer (DISBO) must set up a separate account specifically for the recycling program. The ship's XO and EO should be named secondary custodians, requiring both signatures to sign checks. Checks will be written to procure items necessary for the program and to cover costs of operations (e.g., reimburse the ship for renting a vehicle from the motor pool to transfer the cans to local recycling facilities).

g. Auditing

The primary auditor will be the CO of each particular ship. This audit can take place at the CO's discretion, and at a frequency deemed appropriate. The Supply Officer (SUPPO) will be the officer most directly auditing "the books" for completeness and accuracy. The SUPPO will conduct a formal audit every quarter to ensure the program's financial integrity; findings are submitted to the XO and CO.

E. STARTING A RECYCLING PROGRAM

1. "Top-Down" Leadership

Leadership is the single most important action for the program to be a success. The Commanding Officer must be the biggest advocate of the program and instill its rationale and priority in the crew's mind. A program introduction at a Captain's Call or over the 1MC is an ideal method for initially spreading the word. The crew will perform their duties better and with more enthusiasm if they believe what they are doing is right; that positive attitude begins with the Commanding Officer.

2. Crew Education

It is vital that the crew be introduced and educated about the entire program before it is implemented. Allow them to ask questions and make suggestions on how to best implement the recycling program. Inform them of the manpower and space requirements in advance, as well as the many benefits and rewards inherent in the program.

3. Assignment of Responsibilities

The entire crew must understand that it is an "all-hands" recycling program. It is a continual process which never takes a holiday or break. An Environmental Officer (EO) needs to be appointed, and other responsibilities assigned. Requisite authority must be given to the EO's to allow them to successfully complete their duties. Follow-ups and inspections can ensure that the program has been implemented and is operating effectively.

4. Source Segregation

Aluminum and tin are separated from the regular waste stream most easily and efficiently at the source. Wherever the product is used, it should be placed in a separate container for eventual deposit at the CRC. Decentralized source segregation eliminates duplication of work and is convenient and sanitary. Picking through garbage for recyclables is very distasteful and presents serious potential health risks.

5. Central Collection and Storage Facility

A central space for collecting, processing, and storing recyclables before off-loading them is critical to the recycling program's overall success for several reasons. First, it minimizes bacterial growth and contamination throughout the ship. It also maintains the quality of life by keeping odors and trash bags out of the crew's common areas. It is easier to ensure that the one space (CRC) is maintained in spotless condition, rather than maintaining many areas throughout the ship. It is also easy to clean and perform preventive and routine insecticide spraying.

6. Flexibility and Continuous Improvement

It is important to remain flexible and adaptive to changes during the program's initial weeks/months of operation. Each ship must customize its program, and develop its own implementation methods. A positive attitude and searching for continuous improvement will help alleviate many of the initial problems and frustrations.

7. Required Equipment

Five items are necessary to implement an aluminum and tin recycling program on Naval Combatants: aluminum can crusher, tin can crusher, Odor Barrier Bags, heat sealer, and a wet-dry vacuum. Both can crushers and the wet-dry vacuum are available commercially on the open market; the OBB bags and associated heat sealer are available via the Navy Stock System.

a. Can Crushers

Both can crushers can be either wall-mounted or stand-alone. The recommended aluminum can crusher is approximately 12"x5"x3" and can be attached to any vertical surface with a few screws. These crushers should be installed throughout the ship in spaces where a significant number of sodas are consumed. When sailors finish the sodas, they can crush the cans immediately and deposit them in a separate container specifically for aluminum storage. This will increase storage capacity in the workspace before recyclables are transferred to the CRC.

b. Odor Barrier Bag Kit, Heat Sealer and Wet-Dry Vacuum

The Odor Barrier Bags are stored on a roll which can be easily mounted on a bulkhead in the CRC. Only one roll is required; however, if a ship desires both sizes of OBB bags, then a second roll rack will need to be mounted. The heat sealer is approximately 12"x5"x5." It is also mounted on a bulkhead for hands-free operation. The wet-dry vacuum need only be secured-for-sea by a rope or bungee cord.

8. Locating a Buyer of Recyclables

There are many sources to locate buyers of recyclable materials. Civilian recycling centers are often referred to as recycling vendors or Independent Material Buyers (IMB). Most likely, the ship's home port Naval Station has a recycling program with connections to recycling vendors. There are also many other methods to locate a local recycling center, a few of which are listed below:

- Local telephone book
- Municipal recycling offices
- Local Chamber of Commerce
- Local/Regional recycling organizations
- National Trade Associations
- Steel Recycling Institute

[Ref.28:p.8]

Another option is to turn the recyclables in to the nearest Defense Reutilization and

Marketing Office (DRMO). However, the subsequent revenues will be much less than dealing directly with a recycling vendor or an IMB (discussed in detail in Chapter V).

9. Start-Up Funding for Recycling Program

a. Operating Funds

Ship's Operating Funds can be used to start the recycling program, although the fiscal requirements will not be excessive. The following items need to be funded initially in order to start the onboard aluminum and tin recycling program:

Item	Quantity	Unit Cost	Total Cost
Aluminum Can Crusher	25*	$10.00*	$250.00
Tin Can Crusher	1	$200.00*	$200.00
Odor Barrier Bags (OBB)	10 Rolls**	$110.00***	$950.00****
OBB Heat Sealer	1	$1750.00	$1750.00
Wet-Dry Vacuum	2	$75.00	$150.00
		TOTAL	$3300.00*****

*Approximations

**Large OBB's are 50 bags/roll, Small OBB's are 100 bags/roll

***Small OBB's are $80.00/roll

****Purchase mix of 5 rolls large OBB's & 5 rolls small OBB's.

*****Total will be slightly higher (approx $1000.00) for the Arleigh Burke Class Destroyer to build and install recyclables storage container on flight deck.

Table 7

b. Supplemental Funding

The ship can request supplemental funding from its Immediate Superior In

Command (ISIC). This supplemental can be submitted individually, or as a item in the ship's annual submission of its Unfunded Requirements List to its ISIC. These funds can be received on a "loan" basis or as a direct allocation.

10. Revenue Generation

Rules regarding the proceeds from the sale of recyclables are contained in OPNAVINST 5090.1B, Environmental and Natural Resources Program Manual. It states that the proceeds must be segregated in a separate "F3875 Budget Clearing Account." The purpose of this account is to earmark the proceeds from selling recyclables to cover costs of operations, maintenance, and overhead for processing and handling the recyclable materials (this is to include the cost of any equipment purchased for recycling purposes). If a balance remains, it may be transferred to the ship's nonappropriated funded Morale, Welfare, and Recreation account as defined in existing DoN regulations [Ref.11:p.10-7].

V. DATA PRESENTATION AND ANALYSIS

A. BACKGROUND

The primary goal of this research is to identify the feasibility of recycling aluminum and tin onboard U.S. Naval Combatants. It includes research from four classes of U.S. Naval Combatants and generates ship-specific recommendations for implementing a recycling program.

B. DATA GATHERING STRATEGIES

The majority of data in this thesis was observational, although archival and opinion data was also obtained. The observational data was gathered during several ship visits inport on USS SIDES (FFG-14) an Oliver Hazard Perry Class Frigate, USS OLDENDORF (DD-972) a Spruance Class Destroyer, USS JOHN S. MCCAIN (DDG-56) an Arleigh Burke Destroyer, USS DAVID R. RAY (DD-971) a Spruance Destroyer, USS REID (FFG-30) an Oliver Hazard Perry Class Frigate, and a three day underway period onboard USS PRINCETON (CG-59) a Ticonderoga Class Cruiser.

a. Ship visits (inport and underway)

Ship visits were conducted onboard each of the four classes of Naval combatants being studied: Ticonderoga Class Aegis Cruisers, Oliver Hazard Perry Class Frigates, Arleigh Burke Aegis Destroyers, and Spruance Class Destroyers. The first ship visited was a Ticonderoga Class Cruiser, and it was there that the data gathering methodologies and procedures were devised, tested, and proven, before visiting the other ship types.

b. *Space Inspections*

Exhaustive space inspections were conducted on each ship to determine which, if any, spaces were suitable for crushed can storage. Factors which were used as suitability criteria included:

- *Proximity to the galley* (the closer to the galley the better)(tin only).
- *Ventilation Systems* (very important to have excellent installed ventilation systems to maintain positive habitability).
- *Size* (had to be of sufficient size to house the can compactor and sufficient storage room).
- *Space Contents* (the space needed to be relatively empty and not contain many protruding objects which could snare or rip the Odor Barrier Bags).
- *Proximity to skin of ship* (ideally, the space would be located near a hatch leading to the ship's exterior to reduce the number of internal passageways through which the OBBs are carried).
- *Availability* (space must be currently used for non-critical purposes and available for immediate use as a storage facility).

c. *Interviews*

In order to determine the resistance of a ship's crew to implementing an aluminum and tin recycling program onboard their ship, several groups of individuals were interviewed.

(1) Galley Personnel. The first interviewed were enlisted personnel who worked in the galley (mostly Mess Specialists) since they are the ones whom the program would most directly affect. The predominant concerns at their level were an increase in workload rinsing the cans, inconvenience in source segregation, and the absence of a rewards structure. Overall, there was cautious optimism in supporting the program.

(2) Supply Officers. Food Service Officers and the Supply Officers were interviewed to determine their anticipated problems with the program's implementation. Manpower and sanitation concerns predominated in these conversations. They were concerned that the Supply Department would be the sole caretaker of the program, and were initially cautious. As a whole, there was general support for the program at this level.

(3) Executive Officers. Executive Officers interviewed were also initially cautious due to manpower issues, but overwhelmingly supportive of the program. They shared the concerns of the galley workers and Supply Officers, but were confident that the program could be implemented successfully. Their other concerns included storage, habitability, quality of life, and cost-benefit analysis results.

(4) Commanding Officers. Commanding Officers interviewed were very aware of the impending requirements of "zero discharge" by 31 Dec 1998. They were interested in ideas which could help them comply with this law, minimize impact on the crew, and not jeopardize combat effectiveness and operational readiness of their ship.

They shared the concerns stated above by other crewmembers, and overwhelmingly believe that it is feasible and can be successfully implemented.

d. Archival Data

The bulk of archival data was obtained from DoN Instructions, point papers from various consulting agencies, and reports generated by DoD contractors and support agencies working on solid waste disposal issues. Legislative Branch activities, along with other federal agencies such as the Environmental Protection Agency, provided valuable sources of information.

C. ANALYSIS ASSUMPTIONS

In collating and organizing the data, numerous assumptions were made. The assumptions help focus the data and avoid over-generalizations. They also provide the specifics regarding how the calculations were computed, revealing both their strengths and weaknesses. The assumptions used in the calculations are as follows:

1. Sources of Recyclable Aluminum and Tin Onboard U.S. Naval Combatants

There is only one significant source each for aluminum and tin onboard Naval Combatants. The source of recylable aluminum is vending machines which sell 12 ounce soda cans. For tin cans, the galley is the single source. The five types of cans collectively compose the aluminum and tin waste stream generated by Naval Combatants. The sizes and weights of the cans are as follows:

SIZE AND WEIGHT OF ALUMINUM AND TIN CANS ONBOARD U.S. NAVAL COMBATANTS			
Can Type	**Height** (inches)	**Diameter** (inches)	**Weight** (pounds)
aluminum "soda" can	4.75 in	2.50 in	.039 lbs
# 10 Tin can	7.00 in	6.00 in	.606 lbs
# 3 cylinder	7.05 in	4.25 in	.328 lbs
# 2 1/2 can	4.63 in	4.00 in	.231 lbs
# 300 tin can	3.75 in	2.00 in	.026 lbs

Table 8

2. Average Mixtures

When calculating the approximate amount of waste that will be generated by a particular ship per day, it was necessary to calculate the relative usage of the four types of tin cans consumed. The proportion of the four types of tin cans was applied to each ship's individual usage rate to arrive at an "average tin mixture." This ship-specific average mixture is then applied to the ship's inport and underway usage rates. Aluminum can usage rates are then added to "average tin mixture" to determine the approximate amount of waste generated by a particular ship per day.

3. Inport / At-Sea Calculations

It is possible to count the exact days that each of the ships researched was underway in a particular year based on historical data. This would provide absolute accuracy for specific ships, but not for an entire class of ship. Due to changing operational comittments, location in future work-up/deployment cycles, unpredictable occurrences (breakdowns, temporary decrease/unavailability of fuels money, etc) it is difficult to accurately predict the numbers of steaming days per year for each ship type even though numbers steaming days are specifically budgeted each quarter. For calculation purposes, all four ship types will be assumed to be at-sea and inport for six months per year.

4. Can Crushing Processes

a. Aluminum

Due to their malleability and location of use throughout the ships, soda cans are assumed to be crushed with a hand operated, wall-mounted soda can crusher. The can crushers are assumed to be located throughout the ship in all spaces which have high soda consumption.

b. Tin

The tin cans are consumed in the galley, but are not crushed there because there is no space for either the crusher nor a container for the crushed cans. The tin can crusher is an industrial duty hand-operated (either hydraulic or electric) press. It will be located in the CRC.

c. Uniformity

Whatever process is used to crush the aluminum and tin cans, it is considered to be a uniform process. Following each crushing evolution, the resulting crushed can of each type will be of uniform size and shape respectively.

5. Food Consumption Rates

Two different food consumption rates were considered for this research, inport and at-sea. The inport consumption is less than at-sea because a significant portion of the crew either goes home or elects to eat off-ship at night. Additionally, the number of personnel consuming midnight rations (MIDRATS) while inport is limited to those standing night duty watch (very few people) as compared to at-sea when approx one-fourth or more of the crew eat MIDRATS each night. Based on information received from the Supply Officers of each of the ships visited, the consensus was nearly the same. The relationship used to determine the quantity of food prepared (e.g., the quantity of cans consumed) is: underway food consumption = 1.75 inport food consumption.

6. Odor Barrier Bag (OBB)

The Odor Barrier Bags are the interim solution to long term storage of food contaminated wastes onboard Navy ships. The bags afford the ships extra time to store the contaminated wastes before they become a sanitation, habitability, or quality of life concern.

a. Volume Calculations

Based on available volume of the OBB and the volumes of the crushed cans, it is possible to predict the approximate the number of cans that each bag can store. This will provide an estimation of each bag's capacity and also the amount of storage room it will occupy in the CRC. The volumetric calculations of the two sizes of odor barrier bags were performed in an identical manner. For purposes of accuracy, the bags were divided into three separate sections. The three sections were chosen due to the bags' tendency to taper together at both the top and the bottom. The top and bottom sections were calculated as two triangular cylinders. The middle section was calculated assuming rectangular dimensions for the sides.

The following table delineates the measurements and associated volumetric calculations of the large and small OBBs.

ODOR BARRIER BAG (OBB) VOLUMETRIC CALCULATIONS		
SMALL OBB (24"x27")	**Base/Height** (inches)	**Volume** ($inches^3$)
upper section	b = 12" h = 6" l = 24"	864
lower section	b = 12" h = 6" l = 24"	864
middle section	l = 24" w = 12" h = 15"	4320
	TOTAL VOLUME	**6048 in^3**
LARGE OBB (36"x50")	**Base/Height** (inches)	**Volume** (cubic inches)
upper section	b = 20" h = 12" l = 24"	4320
lower section	b = 20" h = 12" l = 24"	4320
middle section	l = 36" w = 20" h = 26"	18720
	TOTAL VOLUME	**27,360 in^3**

Table 9

b. Packing Methodology and Settling

When the OBB's are loaded with the cans, the amount of settling that will occur is based on how the cans were stacked when placed inside the bag. All cans are assumed to be deposited in the bag in a random fashion. As settling occurs over time, it may appear that the bag was not filled completely. The gains in increased numbers of cans per bag due to careful bagging and vigorous shaking to force settling while loading are deemed negligible.

Randomly throwing the crushed cans into the OBBs creates an inherent variability which must be factored into the calculations. This approximate number of cans is used as a reference, and a 30 percent margin of error was allocated above and below that amount. This yields the interval upon which further estimations were based.

7. Revenue Generation

a. Recyclable Resale Rates

The market prices for recyclable products such as aluminum and tin (steel) are volatile. They vary according to location, time of year, quality of recyclables (amount of contamination), and current demand. The revenue estimations are based on the per pound market price for aluminum and tin. This market price was an average market price of several locations throughout the country (both east and west coasts) from October 1994-1995. The revenue calculations are based upon a best and worst case scenario. The best case calculation uses the highest price paid in FY-95 for recyclable aluminum and tin, and the worst case uses the lowest price paid for both materials in FY-95.

D. DATA PRESENTATION

1. Usage Data

(1) Aluminum. All of the aluminum included in this research is aluminum soda cans. These cans are composed of 100 percent aluminum and are in demand in the recycling markets. The table below lists the monthly consumption rates for each specific ship type as per the Food Service Supply ordering records obtained from each ship.

U.S. NAVAL COMBATANT AVERAGE MONTHLY ALUMINUM USAGE DATA				
SHIP TYPE	**INPORT (cans/mo)**	**AT-SEA (cans/mo)**	**AVERAGE (# cans/mo)**	**AVERAGE (# cans/day)**
Aegis Cruiser	5432	10584	8008	267.0
Oliver Hazard Perry Frigate	4631	7300	5966	198.9
Aegis Destroyer	5220	9100	7160	238.3
Spruance Destroyer	5340	9684	7512	250.4

Table 10

Average # cans per day = (Avg # cans per month) / (30 days per month)

(2) Tin.

The average usage rates for each ship type are summarized below.

U.S. NAVAL COMBATANT AVERAGE MONTHLY TIN (STEEL) USAGE DATA			
SHIP TYPE	**INPORT (cans/month)**	**AT-SEA (cans/month)**	**AVERAGE (cans/month)**
Aegis Cruiser			
# 2 ½ can	576	1008	792
# 10 can	900	1575	1238
# 3 cylinder	672	1176	924
# 300 can	407	713	560
Oliver Hazard Perry Frigate			
# 2 ½ can	420	735	578
# 10 can	740	1295	1018
# 3 cylinder	380	665	523
# 300 can	280	490	385
Aegis Destroyer			
# 2 ½ can	452	791	622
# 10 can	808	1414	1111
# 3 cylinder	448	784	616
# 300 can	360	630	495
Spruance Destroyer			
# 2 ½ can	329	576	453
# 10 can	812	1421	1117
# 3 cylinder	580	1015	798
# 300 can	374	655	515

Table 11

2. Can Volumetric Analysis

The dimensions of each type of can have been measured and the volume of each can has been determined. Since the cans will be stored only after having been crushed, it was necessary to remeasure each can after being crushed and calculate its "crushed" volume. It is the crushed volume which will be used in storage calculations and further analysis. The table below displays each can measurement and respective volume.

CAN VOLUMETRIC ANALYSIS							
	ORIGINAL SIZE				COMPACTED SIZE		
CAN TYPE	HT (in)	DIA (in)	VOL (in^3)	WEIGHT (pounds)	HT (in)	DIA (in)	VOL (in^3)
Aluminum can	4.75	2.50	23.30	.039	1.05	2.70	6.01
# 2 ½ can	4.63	4.00	58.15	.231	1.50	4.50	23.84
# 10 can	7.00	6.00	197.82	.606	2.00	6.75	70.48
# 3 cylinder	7.05	4.25	99.96	.328	2.15	4.75	37.92
# 300 can	3.75	2.00	11.78	.026	.70	2.10	2.42

Table 12

3. Odor Barrier Bag (OBB)

The Odor Barrier Bag will be the storage mechanism for the crushed aluminum and tin cans. The volume of the large and small OBBs has been calculated to determine how many cans can be stored in each bag. The OBB volume is then compared to the overall usable storage volume to determine how many bags that particular space can store. The ship's usage data is then examined to determine how many days the ship can maintain full operational capability (FOC) without off-loading the recyclables. OBB volumetric capacities are delineated in the table below:

ODOR BARRIER BAG CAPACITIES				
Can Type	**OBB Volume (in^3)**	**Crushed Can Volume (in^3)**	**Avg # Cans per bag**	**Avg # Cans per bag Adjusted ***
SMALL OBB (24"x27")				
# aluminum cans	6048	6.01	1,006	704
# 2 ½ cans	6048	23.84	254	178
# 10 cans	6048	70.48	86	60
# 3 cylinders	6048	37.92	159	111
# 300 cans	6048	2.42	2,499	1,749
LARGE OBB (36"x50")				
# aluminum cans	27,360	6.01	4,522	3,186
# 2 ½ cans	27,360	23.84	1,148	804
# 10 cans	27,360	70.48	388	272
# 3 cylinders	27,360	37.92	721	505
# 300 cans	27,360	2.42	11,305	7,914

Table 13

*The number of adjusted cans per bag reflects random placement of the cans into the OBB and settling that has not occurred. The volume associated with an OBB liner (canvas bag, paper bag, etc) has also been considered and included in the adjusted figure. A thirty percent reduction in volume has been used to adjust these figures.

4. Ship Specific Space Recommendations by Compartment

Following a thorough inspection of all four ship types, several spaces were selected as potential recyclables storage areas. They were selected on the basis of adequate storage room, installed ventilation systems, close proximity to galley, close proximity to the weather decks, and a few other miscellaneous factors. The purpose of this inspection was to determine the approximate volume (cubic feet) of storage room available for the recyclables. From this data, and the usage figures discussed previously, it is possible to estimate the number of days that a particular ship can store its recyclables while at sea. The following table summarizes the findings:

SHIP SPECIFIC STORAGE RECOMMENDATIONS BY COMPARTMENT				
SHIP TYPE	**COMPART-MENT #**	**NAME**	**SIZE (LxWxH) (feet)**	**TOTAL VOLUME (feet ^{3})**
Aegis Cruiser				
	01-148-1-Q	Fan Room	5x10x7	350
	3-426-2-A	Ordinance Equipment Storeroom	5x10x7	350
	2-464-1-L	Battery Shop	10x5x7	350
	2-464-0-A	Aft Pallet Staging Area	5x5x5	125
		Anchor Handling / Eqpt Storeroom	5x5x5	125
			TOTAL	**1300 ft^3**
Oliver H. Perry Frigate				
		Either Port or Starboard Helicopter Hangers	25x6x6	900
			TOTAL	**900 ft^3**
Aegis Destroyer				
	01-205-01-Q	Pallet Truck Stowage / Battery Charging Room	10x10x5	500
		Forward Section of Flight Deck (stbd side),* near aft decon entrance	12x6x8	576
			TOTAL	**1076 ft^3**

* Assumes construction of a storage container on forward section of the Arleigh Burke's flight deck (adjacent to the entrance to Aft Decon). The storage container must be constructed of 100 percent aluminum and permanently welded to the flight deck. It must be constructed to prevent any Foreign Object Damage (FOD) from endangering helicopter operations. The storage container must also be grounded and coated with Radar Absorbing Material (RAM) to help reduce its radar return characteristics.

SHIP TYPE	COMPART-MENT #	NAME	SIZE (LxWxH) (feet)	TOTAL VOLUME ($feet^3$)
Spruance Destroyer				
	1-434-2-L	Aft Decon	6x4x6	144
	1-382-2-Q	Trash Room	13x6x7	546
	1-426-6-L	Aft Decon	8x4x6	192
	2-382-4-Q	ER09 Workshop**	6x5x5	150
			TOTAL	**1032 ft^3**

** The Spruance Class ships will have a Plastics Waste Processor (PWP) installed in the trash room (1-382-2-Q). The resulting plastic bricks will be deposited through a hole in the deck to the compartment directly below, which is the ER09 Workshop (2-382-4-Q) for storage. Since the plastic bricks are relatively small in size, there is room to store both cans and plastic, as the total space contains approximately 200 cubic feet usable storage space.

Table 14

5. Ship Specific Storage Requirements

From each ship's usage data and the volumetric calculations performed above, it is possible to accurately determine the future storage requirements for each class of ship. It is this storage requirement which will be compared to the available storage spaces onboard to determine the maximum number of sustainable days underway without severely degrading combat effectiveness. The table below outlines the storage requirements:

SHIP SPECIFIC STORAGE REQUIREMENT PER MONTH				
SHIP TYPE	**TYPE CAN**	**AVERAGE MONTHLY USAGE (# cans)**	**CRUSHED VOLUME PER CAN (inches ^{3})**	**TOTAL VOLUME REQUIRED (inches ^{3})**
Aegis Cruiser				
	Aluminum	8008	6.01	48128
	# 2 ½ can	792	23.84	18881
	# 10 can	1238	70.48	87254
	# 3 cylinder	924	37.92	35038
	# 300 can	560	2.42	1355
			TOTAL	**190,656 in^3**
Oliver H. Perry Frigate				
	Aluminum	5966	6.01	35855
	# 2 ½ can	578	23.84	13779
	# 10 can	1018	70.48	71749
	# 3 cylinder	523	37.92	19832
	# 300 can	385	2.42	932
			TOTAL	**142,147 in^3**
Aegis Destroyer				
	Aluminum	7160	6.01	43032
	# 2 ½ can	622	23.84	14828
	# 10 can	1111	70.48	78303
	# 3 cylinder	616	37.92	23359
	# 300 can	495	2.42	1198
			TOTAL	**160,720 in^3**

SHIP TYPE	TYPE CAN	MONTHLY USAGE (# cans)	CRUSHED VOLUME PER CAN (inches ^{3})	TOTAL VOLUME REQUIRED (inches ^{3})
Spruance Destroyer				
	Aluminum	7512	6.01	45147
	# 2 ½ can	453	23.84	10799
	# 10 can	1117	70.48	78726
	# 3 cylinder	798	37.92	30260
	# 300 can	515	2.42	1246
			TOTAL	**166,178 in^3**

Table 15

6. Estimated # Days A Ship Can Maintain Full Operational Capability (FOC) Without A Recyclables Off-Load

The following formula is used to calculate the estimated number of days that each ship type can maintain underway while still maintaining Full Operational Capability (FOC). Full Operational Capability is defined as the ship being able to successfully perform all duties assigned. For the purpose of this thesis, a ship will be considered FOC if it has not exhausted all of its available storage space for recyclables.

Formula: (# cans consumed per day at-sea) X (Volume of crushed can) = Storage volume required per day at-sea

(Total available storage volume per ship) / (Storage volume required per day) = Estimated Days of Full Operational Capability without at-sea recyclables off-load

SHIP SPECIFIC STORAGE REQUIREMENTS AND CAPACITIES			
SHIP TYPE	**TOTAL AVG VOL REQ PER DAY (inches^3/day)**	**TOTAL AVG VOL AVAIL STORAGE (inches^3)**	**ESTIMATED # DAYS FULLY OPERATIONAL CAPABLE**
Aegis Cruiser			
Aluminum	1604 in^3		
Avg Tin Mix	4751 in^3		
TOTAL	**6355 (in^3/day)**	**2,246,400 in^3**	**353 days**
Oliver H. Perry Frigate			
Aluminum	1195 in^3		
Avg Tin Mix	3543 in^3		
TOTAL	**4738 (in^3/day)**	**1,555,200 in^3**	**328 days**
Aegis Destroyer			
Aluminum	1434 in^3		
Avg Tin Mix	3923 in^3		
TOTAL	**5357 (in^3/day)**	**1,859,328 in^3**	**347 days**
Spruance Destroyer			
Aluminum	1505 in^3		
Avg Tin Mix	4034 in^3		
TOTAL	**5539 (in^3/day)**	**1,783,296 in^3**	**322 days**

Table 16

This table indicates that there is adequate storage space for the crushed aluminum and tin cans onboard all four ship classes. It also reveals that the ships will not be limited because of the number of underway days without a recyclables off-load. One important consideration is that this table does not consider the volume of the remainder of the ship's waste stream which is significant.

7. Ship Specific Estimated Monthly Revenues From Recycling Aluminum And Tin

After the ship has collected its recyclables and returned to port, it has basically four options: Option 1, ship's personnel transport the materials to the local Defense Reutilization and Marketing Organization (DRMO) and relinquishes custody to them; Option 2, ship's personnel transports the recyclables to an Independent Material Buyer (IMB), more commonly known as a local recycling center or Resource Recovery Center (RRC); Option 3, the ship donates the recyclables to the naval station recycling center; Option 4, the ship discards the recyclables with the regular waste stream.

a. Option 1: DRMO

When the materials are transported to a DRMO, they are weighed and logged in. DRMO personnel record the type of material and its weight, and issue a receipt. At a later date, DRMO sells the material and remits the funds (minus DRMO expenses) back to the ship [Ref.24:p.6].

The DRMO method has a few major drawbacks. First, there is a time lag, sometimes months, between the custody transfer and when the ship receives the revenues from the selling of the recyclables. Also, the price DRMO receives is normally much lower than the price the ship could obtain had the materials been taken directly to a local recycling center. DRMO typically has long-term fixed contracts with selected buyers, which depresses the selling price. By its nature, recyclables resale values are very volatile, and these fixed contracts tend to keep the resale price depressed because they are inflexible to market conditions.

An example of how much money is forgone by transferring recyclables to a DRMO is illustrated by the Pearl Harbor Naval Base Recycling Program. The recycling program is managed by Mr. Mark Wells, who coordinates both the materials received from the ships and the logistics involved in the selling of those materials. Not satisfied with the prices he was receiving from DRMO for his recyclables, he sought independent material buyers to purchase the materials. After switching to independent buyers, Mark increased the annual sales revenue over the previous year by 320.72 percent [Ref:29:p.4].

b. Option 2: Independent Material Buyer (IMB)

When the ship transports recyclables directly to the local recycling center, a IMB representative will inspect the recyclables for contamination and quality. Contamination refers to major food wastes on the cans. Quality is associated with the presence of other material types with the recyclables (e.g., garbage, plastics, paper, cardboard, and other metals). The price is based on the current market conditions and quality of materials. Once priced and weighed, a check is immediately issued.

The IMB option has several advantages. First, it is less work and hassle than DRMO. It involves only one transaction, that being depositing the recyclables and collecting the cash. The entire transaction is completed at the same time. Additionally, the IMB will frequently pick up the recyclables from the pier. Third, a check is issued immediately.

c. Option 3: Deposit with Naval Station Recycling Center

For many ships, depositing with the Naval Station Recycling Center is the most viable option. Normally, recycling containers are conveniently located on the pier. The ship does not have to coordinate their pickup or arrange for transportation to the local recycling center.

Advantages of this option include ease and minimal impact for the crew. The benefits are also distributed to the ship and crew via base-wide MWR programs. However, the ship receives no cash directly for the recyclables because the proceeds are retained entirely by the Naval Station's MWR.

d. Option 4: Deposit with the regular waste stream

Depositing with the regular waste stream is the least feasible of the four options. It takes no more effort to dump the recyclables into the recycling containers on the pier than it does to deposit them into the dumpster. Even if no recycling containers are located on the pier, they are located somewhere on base, probably not very far from the pier. If dumped with regular wastes, all the potential revenues to either the ship or the base's MWR program are foregone. It also increases the cost of hauling away the regular garbage because it adds to the volume and weight.

The following table summarizes the potential revenues from recycling aluminum and tin onboard Naval Combatants:

SHIP SPECIFIC ESTIMATED MONTHLY REVENUES FROM SALES OF RECYCLABLE ALUMINUM & TIN						
SHIP TYPE	**AVG CAN WT (lbs)**	**AVG # CANS (#/month)**	**LOW MKT PRICE ($/lb)**	**HIGH MKT PRICE ($/lb)**	**EST REV LOW ($)**	**EST REV HIGH ($)**
Aegis Cruiser						
Aluminum	.039	8008	.12	.68	$37.47	$212.37
Avg Tin Mix	.298	3514	.0075	.085	$7.85	$89.00
				TOTAL	**$45.32**	**$301.37**
Oliver H. Perry Frigate						
Aluminum	.039	5966	.12	.68	$27.92	$158.22
Avg Tin Mix	.298	2504	.0075	.085	$5.60	$63.43
				TOTAL	**$33.52**	**$221.65**
Aegis Destroyer						
Aluminum	.039	7160	.12	.68	$33.51	$279.24
Avg Tin Mix	.298	2844	.0075	.085	$6.36	$72.04
				TOTAL	**$39.87**	**$351.28**
Spruance Destroyer						
Aluminum	.039	7512	.12	.68	$35.15	$199.22
Avg Tin Mix	.298	2883	.0075	.085	$6.44	$73.02
				TOTAL	**$41.59**	**$272.24**

Table 17

E. SUMMARY

The usage data for aluminum and tin has been determined for each of the four classes of Naval Combatants and the available storage spaces identified. This data was used to predict the volume a particular ship will require each day, and subsequently, the number of days a ship can remain underway without using all of its storage space. Additionally, the estimated revenues a ship can expect based on the high and low 1995 market values of aluminum and tin were presented.

All four classes of Naval Combatants examined in this thesis have adequate storage room to implement an aluminum and tin recycling program. Each has the potential to generate significant revenues to be allocated to the ship's MWR program.

VI. CONCLUSIONS AND RECOMMENDATIONS

All Navy activities shall implement source separation for recycling and develop a single authorized Qualified Recyclables Program.

--OPNAVINST 5090

A. BACKGROUND

Although mandated by OPNAVINST 5090, many ships have not implemented a recycling program citing storage, sanitation, and crew "quality of life" concerns. After reviewing this thesis, however, determining whether to implement an aluminum and tin recycling program onboard U.S. Naval Combatants is much more clear and has one simple answer; it is feasible. Many tangible factors must be considered, such as cost, revenue generation, and marketability of the recyclables. Intangibles such as the Navy being perceived as a good "steward" of the environment, maintaining good public relations, "doing the right thing," and intrinsic pride and satisfaction in making a positive impact on our environment are other considerations worthy of discussion.

1. Assumptions

The conclusions and recommendations are based upon several assumptions. These assumptions are critical in that they define the context in which the recycling program will operate. The following assumptions are used:

1. The recycling program cannot negatively affect the ship's combat effectiveness or operational readiness.
2. Naval missions will not be affected by MARPOL Annex V or any other environmental regulations.

3. The Navy will continue to operate in MARPOL "special areas" in support of National Objectives.
4. The solution does not involve keeping ships inport more often or decreasing lengths of sustained underway periods.
5. CLF ships must acquire a new mission to store/retrograde other ship's solid wastes [Ref.30:p.11].

2. Goals

The conclusions and recommendations consider the following goals of the aluminum and tin recycling program:

1. Maintain ship's maximum operational readiness.
2. Maintain ship's maximum combat effectiveness.
3. Maximize cost savings and revenue generation.
4. Minimize overall crew impact.
5. Maintain crew quality of life and habitability.
6. Reduce ship's negative impact on the environment.
7. Improve ship's overall efficiency and decrease reliance on appropriated funding.

B. CONCLUSIONS

After carefully analyzing whether to implement an aluminum and tin recycling program onboard U.S. Naval Combatants, the following conclusions have been drawn.

1. Implementation

Implementing an aluminum and tin recycling program onboard Naval Combatants is feasible when comparing all costs and benefits. It will reduce a significant portion of the ship's waste stream and provide revenues for the ship's Morale, Welfare, and Recreation fund.

2. Source Segregation

Source segregation is the only viable method of separating aluminum and tin from the balance of the ship's waste stream. The cans can be efficiently and effectively separated from the ship's normal solid waste stream using conveniently located and distinctly marked receptacles throughout the ship.

Segregation has a direct impact on the market price of the ship's recyclables. The "quality" of the recyclables is determined by the amount of contamination (other wastes) mixed in with the cans, and source segregation helps reduce contamination.

3. Storage

All four Naval Combatants investigated have sufficient space to store crushed aluminum and tin cans for extended periods of time. Many workspaces and berthing compartments have adequate room to store crushed aluminum cans for extended periods before being deposited in the Central Recycling Collection (CRC) space. Aluminum and tin crushed can storage will have no effect on operational readiness or combat effectiveness.

4. Market for Recyclables

There currently exists a strong and viable market to purchase aluminum and tin cans from Navy ships. Due to the inherent volatility in the metals market, it is difficult to accurately predict the market price for any given period of time.

5. Mandates

As directed in FY-94 Department of Defense Appropriation Act, the Congressional mandate of "zero discharge" must be complied with by 31 Dec 98. Any further Navy requests to extend this deadline will most likely be denied. Implementing an aluminum and tin recycling program will further assist the Navy in its compliance. It is an effective method of reducing the ship's solid waste stream which must otherwise be disposed at landfills.

6. Revenue Generation

There exists potential for significant revenues by selling the recyclable cans. Estimated figures are delineated in Chapter V. There is an additional "invisible cash flow," known as cost avoidance, associated with converting waste to recyclables. Cost avoidance is the money saved by not having to pay to haul the materials (aluminum and tin) away to landfills with the balance of the ship's waste stream. The cost avoidance could be calculated using costs ($/ton) charged to haul regular wastes to the landfills [Ref.24:p.6]. This savings does not appear on any balance sheet, but is immediate, and can be realized without any specialized processing.

7. Crew Training and Education

Crew training and education are critical to the program's success. Each sailor must understand the importance of the program and the many benefits it creates. The education will instill an "environmental awareness" in each person, likely making them better recyclers and more willing to "actively" participate in the program. This increases the program's efficiency and effectiveness.

8. Top Leadership Support

The champion and most vocal supporter of the program must be the Commanding Officers. They have the ability to instill in the crew the urgency, necessity, and motivation to make the program a success. Additionally, the ship's Officers and Chief Petty Officers must set the example for supporting the program through both words and deeds.

The crew must believe in what they are doing, and feel like they can personally make a difference. This idea has been validated through several psychological studies which have concluded, "persons are less likely to accept their own responsibility for recycling because they don't believe their individual recycling efforts make a difference" [Ref.31:p.575]. Most Commanding Officers have the unique ability to make each person feel like they are "the key link" to the ship's (or program's) success. It is that charisma and enthusiastic spirit which can drive a crew to succeed in implementing this program.

9. Increasing Landfill Disposal Fees

Disposal fees will increase as more ships (not just U.S. Navy vessels) comply with the MARPOL Protocol and bring much larger quantities of waste inport for disposal. This increase in the overall volume of trash being brought ashore for disposal will likely change the structure and prices of trash disposal contracts. It is a problem for both domestic and foreign ports. The current waste disposal contracts for most foreign ports are not written to allow estimations of the impact of increased disposal volumes, especially in MARPOL "special areas" [Ref.30:p.4].

10. Intangible Benefits

Several intangible benefits are realized (nearly guaranteed) with a recycling program. Items such as energy savings, creating a positive Navy public relations image, reducing reliance on virgin raw materials in production processes, and improving the environment are also enjoyed.

11. Self-Sufficiency

After a relatively short period of time, the program should be completely self-sufficient. As delineated in Chapters IV and V, revenues generated from sales should cover the price of equipment, materials, and services required to start-up and operate the program. Barring any unforseen catastrophic circumstances, the program will continue its self-sufficiency indefinitely and deposit all subsequent revenues (minus operating expenses) into the ship's MWR account.

12. Recycling Convenience

The amount of contamination mixed with the recyclables and possible losses of recyclables in the regular waste stream are most likely related to the convenience of recycling to the sailors. When sailors finish a soda and there is a can crusher and recyclable container nearby, they will typically recycle the can. If the recyclable container is too far away and there is a regular waste container nearby, half of them are likely to deposit the can with regular trash. It is therefore vital to ensure that an adequate supply of recyclable containers are dispersed throughout the ship.

13. Minimal Crew Impact

Recent studies of pilot recycling programs on U.S. Navy ships, combined with ship's crew feedback, overwhelmingly support implementing recycling onboard U.S. Naval Combatants. Since the majority of effort in a recycling program involves collecting, storing, and removing the material, this section focuses on the impact on the crew from using, storing, and off-loading the OBB's.

After a trial period using the OBB bags on his ship, the Commanding Officer of USS GRASP commented, "The Odor Barrier Bag program is a functional and effective method of eliminating odor and sanitation problems associated with waste disposal at-sea" [Ref.26:p.17]. After a similar trial period, the Commanding Officer of USS Samuel Eliot Morison had the following remarks, "In regards to implementation of the Odor Barrier Bag program, its increases in manpower requirements were negligible, and no comments or complaints about foul odors were received from any crewmember." He also noted, "Use of the OBB Heat Sealer appealed to the crew's increased awareness of environmental concerns, and crew morale was positively impacted by its use" [Ref.26:p.38].

C. RECOMMENDATIONS

The research question on whether it is feasible to implement an aluminum and tin recycling program onboard U.S. Naval Combatants was answered affirmatively in Chapter V. The benefits inherent with the program far exceed the costs, making it a viable program from any viewpoint. The following recommendations will help minimize the problems when implementing the program.

1. Pier Storage

As previously mentioned, while inport, the recyclables should be stored in separate, specifically designated, containers on the pier. If not available from the Naval Station, the cost of these containers can be cost-shared among other ships sharing the same pier. If available, ships should obtain a 30-40 cubic yard compactor from the Naval

Station's Public Works Department [Ref.24:p.18]. These compactors have the following advantages:

1. Increase the mass density of the solid waste.
2. Blocks of compressed cans are easier to handle and move.
3. The compressed blocks limit the entry of sea gulls and other small animals.
4. Reduce transportation costs to the local vendor because they increase effective storage capacity.
5. Compressed blocks of cans have a more sanitary appearance.

2. Crew Training

As discussed previously, crew training and education about both the program itself and environmental awareness in general will significantly increase the ease with which the program is implemented. It must begin with the Commanding Officer, who can introduce the program in a variety of methods: 1MC broadcast, Captain's Call, ship's TV, posters, and Plan of the Day (POD) announcements. Regular reinforcement of the program's benefits can also significantly bolster the crew's support for the program.

3. Awards Program

An awards program centered around the ship's recycling program can provide the needed incentive to encourage active participation in establishing, maintaining, and improving the program. Awards can be given for any reason, such as innovations to increase the program's efficiency and effectiveness, or to save time and money.

The awards can be given by the CO on a regular basis for individual, workcenter, division, or department level achievements. The ship can also compete for the Department of Defense Environmental Award and the Chief of Naval Operations

Environmental Quality Award.

Commanding Officers should use some type of an awards program to help motivate the crew and improve the overall program. This positive reinforcement can help keep the program from becoming monotonous, which can lead to crew apathy and eventual program failure. A recent study concluded, "monotony and boredom in recycling has been cited as one reason why recycling behavior has deteriorated over time" [Ref.31:p.575].

Commanding Officers can fight boredom and monotony by reminding the crew about the program's benefits. Publishing the revenues deposited in the ship's MWR account for the previous month, quantities of wastes recycled, and the positive impact on the environment are all messages which can keep the crew "onboard" with the program.

4. Constancy of Purpose

From the Commanding Officer down to the newly-reported Seamen Recruit, there must be an unfaltering commitment to the program's success. It must be an all-hands effort to make it "transparent" to the crew. If everyone does their share, the work involved will be evenly distributed and soon become routine.

Everyone must be involved and take a personal stake in the program. Daily inspections by the Executive Officer during his Messing and Berthing Inspections is an ideal time to also examine the status of the recycling program and determine if any changes need to be made. For instance, a visual inspection of the contents of the trash can determine if any recyclables are being lost in the regular waste stream.

D. SUMMARY

Implementing an aluminum and tin recycling program onboard U.S. Naval Combatants is critical to the Navy's ability to comply with environmental legislation and maintain combat effectiveness and readiness. At risk is the Navy's ability to comply with "zero discharge" by 31 December 1998. If the Navy does not comply, they may be forced to limit or potentially cease some operations. At risk also is the preservation of our oceans and seas as well as the tremendous opportunity costs of not recycling and reusing shipboard resources. Shipboard resources are extremely limited, and utilizing them to their fullest capacity is in the best interest of the ship, our Navy, and our Nation.

APPENDIX: ODOR BARRIER BAG (OBB)

The following information pertains to ordering OBB items:

ODOR BARRIER BAG (OBB) COMPONENTS

ITEM	NAVY STOCK NUMBER (NSN)
Odor Barrier Bag, large 36"X50"	8105-01-392-6515
Odor Barrier Bag, small 24"X27"	8105-01-392-6510
Heat Sealer (Doboy model HS-B)	3540-00-819-8837
Vacuum Pump	Commercially available Wet-Dry vacuum

[Ref.25:p.2].

After years of research, development, testing, and evaluation, the resulting OBB's had the following characteristics:

Property	Typical Value	Units	Test Method
Thickness	5.0	Mils	ASTM 0-646-67
Tensile Strength	md 12,500 cd 11,200	Grams per inch	ASTM D-882-611
Elongation at Break	md 560 cd 550	Percent	Not listed
Tear Strength (Elmendorf test)	md 1410 cd 930	Grams	ASTM 689
Impact Strength	> 1200	Grams (Dart W50)	ASTM D-1709

[Ref.26:p.39]

ACRONYMS

AF- Appropriated Funds

APPS- Act to Prevent Pollution from Ships

ASTM- American Society for Test and Materials

CBO- Congressional Budget Office

CDNSWC- Carderock Division, Naval Surface Warfare Center, Annapolis Detachment, Annapolis Maryland

CE- Catagorical Exclusions

CEQ- Council on Environmental Quality

CLF- Combat Logistics Force

CNA- Center for Naval Analyses

CNO- Chief of Naval Operations

CNSP- Commander, Naval Surface Forces Pacific

CO- Commanding Officer

COMNAVBASE- Commander, Naval Base

CRC- Central Recycling Collection

DCA- Damage Control Assistant

DEIS- Draft Environmental Impact Statement

DISBO- Disbursing Officer

DLA- Defense Logistics Agency

DoD- Department of Defense

DoN- Department of the Navy

DRMO- Defense Reutilization and Marketing Office

DTRC- David Taylor Reseach Center, Annapolis Maryland

DUSD(ES)- Deputy, Under Secretary of Defense (Environmental Security)

EA- Environmental Assessment

EIS- Environmental Impact Statement

EO- Environmental Officer

EPA- Environmental Protection Agency

EVOH- Ethylene Vinyl Alcohol

FEIS- Final Environmental Impact Statement

FOC- Full Operational Capability

FOD- Foreign Object Damage

FONSI- Finding Of No Significant Impact

FY- Fiscal Year

GAO- General Accounting Office

GSA- Government Services Administration

HAC- House Appropriations Committee

HASC- House Armed Services Committee

IMB- Independent Material Buyer

IMO- International Maritime Organization

ISIC- Immediate Superior In Command

LEIS- Legislative Environmental Impact Statement

LLDPE- Linear Low Density Polyethylene

LOGREQ- Logistics Requirement

MARPOL- International Convention for the Prevention of Pollution from Ships

MDMAA- Mess Deck's Master-At-Arms

MPPRCA- Marine Plastic Pollution Research and Control Act

MFA- Major Federal Action

MIDRATS- Midnight Rations

MRF- Material Recovery Facility

MS- Mess Specialists

MSG- Message

MWR- Morale, Welfare, and Recreation

NAF- Non-Appropriated Funds

NAFAC- Naval Facilities Engineering Command

NATO- North Atlantic Treaty Organization

NAVSEA- Naval Sea Systems Command

NAVCOMP- Navy Comptroller

NAVSUP- Commander, Naval Supply Corps

NELP- Navy Environmental Leadership Program.

NEPA- National Environmental Policy Act

NLT- Not Later Than

NOV- Notice of Violations

NSTM- Navy Systems Technical Manual

O&M- Operations and Maintenance

OMB- Office of Management and Budget

OPN- Other Procurement Navy

PE- Poly Ethylene

POD- Plan Of the Day

PPA- Pollution Prevention Act

PRIME- Plastics Removal In the Marine Environment

PWP- Plastics Waste Processor

QRP- Qualified Recycling Program

RAM- Radar Absorbing Material

RDT&E- Research, Development, Test & Evaluation

ROD- Record of Decision

RR- Recovery Rate

RRC- Resource Recovery Center

SAC- Senate Appropriations Committee

SASC- Senate Armed Services Committee

SBW- Shipboard-Generated Waste

SECNAV- Secretary of the Navy

SMDR- Senior Medical Department Representative

SOP- Standard Operating Procedures

SPCC- Ships Parts Control Center

SUPPO- Supply Officer

UNREP- Underway Replenishment

VERTREP- Vertical Replenishment

VOL- Volume

XO- Executive Officer

GLOSSARY / DEFINITIONS

ANTARCTIC REGION- Any area south of sixty degrees south latitude.

APPROPRIATED FUNDS (AF)- Funds appropriated on an annual basis by the Congress of the United States to be used for a specific purpose.

ACT TO PREVENT POLLUTION FROM SHIPS (APPS)- Legislation passed by Congress on 221 October 1980. It suggested that ships minimize the materials dumped into the ocean when practicable. It had no enforcement mechanisms, and therefore did not modify or change any Navy regulations.

BALTIC SEA- Area included the Baltic Sea proper with the Gulf of Bothnia, the Gulf of Finland, and the entrance to the Baltic Sea bounded by the parallel of the Skaw in the Skagerrak 57° 44.8' North.

BLACK SEA- Area includes the Black Sea proper with the boundary between the Mediterranean and the Black Sea constituted by the parallel 41° North.

CATEGORICAL EXCLUSION- A category of actions that do not have, under normal circumstances, individually or cumulatively, a significant effect on the human environment or that have been previously found to have no such effect as a result of procedures adopted by the Navy for implementing the Council on Environmental Quality (CEQ) regulations and for which, therefore, neither an Environmental Assessment (EA) nor an Environmental Impact Statement (EIS) is required.

COMMINUTED/GROUND GARBAGE- see pulped garbage

DRAFT ENVIRONMENTAL IMPACT STATEMENT (DEIS)- Statements prepared for actions that may have a significant impact on the quality of the human environment or that are potentially controversial in environmental effects.

ENVIRONMENTAL ASSESSMENT (EA)- A concise public document that provides sufficient evidence and analysis for determining whether to prepare an Environmental Impact Statement (EIS) or a Finding Of No Significant Impact (FONSI). It assists the Navy's compliance with the National Environmental Policy Act (NEPA).

ENVIRONMENTAL OFFICER- A person designated by the ship's Commanding Officer to oversee the ship's recycling program, among other duties.

FINAL ENVIRONMENTAL IMPACT STATEMENT (FEIS)- A completed statement that incorporates all pertinent comments and information made as a result of review of the Draft Environmental Impact Statement (DEIS). The FEIS is filed with the Environmental Protection Agency (EPA) and distributed to recipients of the DEIS.

GARBAGE- Foods, food wastes of any sources, with or without minor paper goods included, but excluding wrappers, containers, packaging, and disposable serving materials.

HUMAN ENVIRONMENT- A term used in NEPA to describe the natural and physical environment and relationship of people with that environment.

IMPACT- A term used in NEPA synonymous with effects, and includes direct, indirect, and cumulative impacts.

INDEPENDENT MATERIAL BUYER (IMB)- An activity not affiliated with the Navy, which takes custody of recyclables from a Navy activity in exchange for money.

INTERNATIONAL MARITIME ORGANIZATION (IMO)- A organization of maritime nations whose purpose is to ensure the protection and continued use of the oceans for all the world's peoples.

LEGISLATIVE ENVIRONMENTAL IMPACT STATEMENT (LEIS)- Detailed statement required by law to be included in a recommendation or report on a legislative proposal to Congress.

LOGISTICS REQUIREMENTS (LOGREQ)- A message sent by Navy ships before they enter port detailing any services, requests, food, and parts that will be required when the ship arrives in port. It is used as a coordination tool between the ship and port authorities before the ship arrives.

MAJOR FEDERAL ACTION (MFA)- Any proposed Federal action that has the potential for physical impact on the human environment.

MARKET VALUE- The current price that can be obtained for a particular material on a given day and location.

MARPOL (Marine Pollution)- A treaty signed by the United States and other maritime nations known as the International Convention for the Prevention of Pollution from Ships. It was signed in 1973, and modified in 1978. Commonly known as MARPOL 73/78. It has five annexes, the most significant of which for the U.S. Navy is Annex V, which prohibits the discharge of paper, cardboard, metal, glass, and plastic near land and in "special areas."

MARPOL "SPECIAL AREAS"- A sea area where, for recognized technical reasons in relation to its oceanographic and ecological condition and to the particular character of its traffic, enhanced efforts are required to minimize pollution from ships.

MIDNIGHT RATIONS (MIDRATS)- A fourth meal served each day for those personnel standing watch throughout the night. Typically served from 2300-2400.

MORALE, WELFARE, AND RECREATION (MWR)- Those activities by a military department or furnished by a Department of Defense (DoD) contractor that provide for the comfort, pleasure, contentment, and mental and physical improvement of authorized DoD personnel including recreational and free-time programs, resale merchandise and services, or general welfare.

NON-APPROPRIATED FUNDS (NAF)- Cash and other assets received from sources other than monies appropriated by the Congress of the United States. NAF are government funds used for the collective benefit of military personnel, their dependents, and authorized civilians who generated them. They are not recorded by the Treasurer of the United States.

PERSIAN GULF- Area which includes the sea area located northwest of the rhumb line between Ras al Hadd (22° 30' N, 59° 48' E) and Ras al Fastah (25° 04' N, 61° 25' E).

PLASTIC WASTE PROCESSOR- Machine which heats and compresses plastic wastes into disks or bricks which can be easily stored. Volume reductions of 30:1 are common.

PULPED GARBAGE- pulped, ground, or comminuted garbage or trash capable of passing through a screen with openings no greater than 25 millimeters (0.98 inches)

RECORD OF DECISION (ROD)- A concise summary for publication in the Federal Register of the decision made by the Navy from among the alternatives presented in the Final Environmental Impact Statement (FEIS).

RECOVERY RATE- The percentage of recyclable materials which is recovered from the ship's waste stream for the purpose of recycling. Expressed as a percentage, it is the amount retained for recycling compared to the total materials eligible to be recycled.

RECYCLABLE- Material which still has useful physical or chemical properties after serving its original purpose and therefore can be reused or remanufactured into a new product.

RED SEA- Area which includes the Red Sea proper, including the Gulfs of Suez, Aqaba bounded at the south by the rhumb line between Ras is Ane (12° 8.5' N, 43° 30.2' E) and Husn Murad (12° 40.4' N, 43° 30.2' E)

SCULLERY- A space located adjacent to the ship's galley for the purpose of rinsing and washing materials used in the preparation of the ship's food.

SHIP- A vessel of any type whatsoever operating in the marine environment.

SOLID WASTES- Garbage, trash, sludge, and other discarded solid materials resulting from industrial and other shipboard activities. It does not include solids or dissolved material in domestic sewage or other significant pollutants in water resources, such as silt, dissolved or suspended solids in industrial wastewater effluent, or other common water pollutants.

SOURCE SEPARATION- The separation of different type of wastes directly after consumption, normally in separate containers.

SPECIAL AREA- A sea area where, for recognized technical reasons in relation to its oceanographic and ecological condition and to the particular character of its traffic, the adoption of special mandatory methods for the prevention of sea pollution by solid waste is required. Special areas include the following: The Mediterranean Sea, Baltic Sea, Black Sea, Red Sea, and the Persian Gulf.

TIN CAN- Term used in this thesis to represent a ferrous steel can.

TRASH- Dry solid waste excluding ordnance and garbage.

TRI-WALL- A standard storage container made of heavy duty corrugated cardboard roughly three feet high, and storage capacity of 44 cubic feet.

UNIT PRICE- Unit price of materials usually expressed in the form $ per weight (e.g., $/ton or $/lb)

UNDERWAY REPLENISHMENT (UNREP)- An evolution involving two ships on the high seas which transfer goods (usually fuel and food) to one another by means of a tensioned spanwire between both ships.

VERTICAL REPLENISHMENT (VERTREP)- An evolution where materials (food, mail, parts, etc) are delivered via helicopter. Usually accomplished with two ships in close proximity and the helicopter transiting between the two ships with the cargo in a sling beneath the helicopter.

VOLUME- Internal capacity of a given object measured in cubic inches.

WASTE- Useless, unneeded or superfluous matter which is to be discarded.

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