United States Coast Guard
U.S. Department of Homeland Security

Disposal of Pyrotechnic Visual Distress Signals

An Interactive Qualifying Project submitted to the faculty of
Worcester Polytechnic Institute
in partial fulfillment of the requirements for the Degree of Bachelor of Science

Sponsoring Agency: United States Coast Guard Headquarters, Washington, D.C.

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Abstract

The United States Coast Guard sought a safe, environmentally sound disposal method for expired boat safety flares (Pyrotechnic Visual Distress Signals). Drawing on a model Canadian program and extensive study of various alternatives, we developed a four-phase process: motivating boaters to bring expired flares to local collection sites, storing flares safely at those sites, transporting them legally and economically to EPA-approved incinerators, then disposal via incineration. We recommended funding a pilot program run by a volunteer boating organization to validate all phases of this process.

Acknowledgements

We would like to give a special thanks to our liaison, Mr. Martin Jackson of the Lifesaving and Fire Safety division, as well as our sponsoring agency, the United States Coast Guard, for the support and direction given on our project. We would also like to thank Mr. Philip Cappel and Mr. Joseph Carro from the Recreational Boating Safety division of the Coast Guard for providing the guidance and resources needed to complete our project. Thanks also go to all individuals interviewed who helped make our project and final recommendations possible.

We hope that the recommendations made by our team, to the United States Coast Guard, will help provide the steps towards creating a pilot program to dispose of marine flares.

Finally, we would like to thank our advisors, Professor Paul Davis and Professor James Hanlan, for their guidance and support. Their feedback and contributions were invaluable to the success of our project.

Glossary of Terms

ABYC®: American Boat and Yacht Council

ATF: Bureau of Alcohol, Tobacco, Firearms, and Explosives

b: Total Number of Registered Recreational Boats in the 23 States that were represented in the Model (for calculation)

CFL: Compact Fluorescent Lamps

CPS-ECP: Canadian Power and Sail Squadrons

DOT: Department of Transportation

E-Waste: Electronic Waste

EPA: Environmental Protection Agency

EX: Explosives

FBR: Fluid Bed Reactor

FDA: Food and Drug Administration

FDEP: Florida Department of Environmental Protection

i: Summation Index Representing Each Summation Iteration (for calculation)

LHAAP: Longhorn Army Ammunition Plant

NRC: Nuclear Regulatory Commission

p: Number of Registered Recreational Boats in the State in which the Particular Coast Guard Station is located (for calculation)

PHMSA: Pipeline and Hazardous Materials Safety Administration

PRM: Perchlorate-respiring Microorganisms

PVDS: Pyrotechnic Visual Distress Signals

REMTC: Reactive & Explosive Materials Training Corporation

s: Distance from each Coast Guard location to the appropriate Clean Harbors® Facility (for calculation)

SD: Scaled Distance (for calculation)

TCLP: Toxicity Characteristic Leaching Procedure

UPS®: United Parcel Service

USCG: United States Coast Guard

VDS: Visual Distress Signal

WPI: Worcester Polytechnic Institute

Executive Summary

One of the Coast Guard's missions is marine environmental protection. The Lifesaving and Fire Safety and Recreational Boating Safety divisions of the United States Coast Guard Headquarters in Washington, D.C. sought a disposal method for expired Pyrotechnic Visual Distress Signals (PVDS), more commonly known as flares. We recommend an environmentally friendly and financially feasible flare disposal program in which boaters are willing to participate while adhering to federal regulation.

Background

PVDSs are a means of alerting search and rescue teams of emergency situations encountered by boaters. With a lifespan of 42 months, the number of expired flares mounts rapidly due to the infrequency of their use. Today, the Coast Guard requires many vessels operating within United States coastal waters, the Great Lakes, territorial seas, and any body of water where the waterway is more than two nautical miles wide to carry multiple visual distress signals ("A Boater's Guide to the Federal Requirements for Recreational Boats and Safety Tips," 2010).

One factor that contributes to the difficulty of PVDS disposal is flares' classification by the Department of Transportation (DOT) as class 1.4 explosives, resulting in strict regulations regarding their transportation (GPO, 2014d). Another factor is the Bureau of Alcohol, Firearms, Tobacco, and Explosives' (ATF) requirement that expired flares be stored in type 4 magazines (GPO, 2014e). Due to these obstacles, the current means of flare disposal are limited: donate to local law enforcement for training, legally ignite them, or dispose of them through commercial hazardous waste disposal facilities.

Methodology

Our goal was accomplished by completing the following objectives:

1. Research and develop a thorough understanding of existing and past disposal methods and their individual merits and shortcomings;
2. Develop solutions to the shortcomings of the disposal strategies identified in Objective 1;
3. Develop a recommendation based on our research, case studies, and collected data.

To complete these objectives we interviewed flare manufacturers and retailers, the American Boat and Yacht Council (ABYC®), the Florida Department of Environmental Protection (FDEP), waste disposal companies, waste transfer facilities, the DOT, the ATF, R &

R Trucking Inc., and the United Parcel Service (UPS®). The information acquired from these interviews provided us with an understanding of past disposal methods and their shortcomings while helping us circumvent these issues.

Key Findings

- In May 2014, the Canadian Power and Sail Squadrons (CPS-ECP), working in collaboration with Transport Canada and CIL/Orion®, ran a pilot program to collect and dispose of expired flares. To fund the program, the CPS-ECP received a grant for $31,890 from Transport Canada that accounted for 75% of the total cost for the collection program. The final 25% was funded directly by the CPS-ECP. Flares were collected at local retailers in nine different locations during pre-determined flare collection days. The CPS-ECP marketed these events by encouraging boaters to attend through advertisements on online boating sites. The resulting attendance allowed the CPS-ECP to collect 10,427 flares, exceeding its goal of 10,000 (Gullick, 2014).
- Our research showed that people are more willing to recycle if social pressures and specific advertisements are used to encourage a particular desired behavior (Burn & Oskamp, 1986). Another study indicated that convenience and duration of the disposal process significantly impacted participation. Finally, a different study showed that inadequate monetary incentives can backfire and do not teach citizens the necessity of environmentally friendly actions.
- Flares can be collected at waste transfer stations, marinas, or retailers if ATF-approved type 4 storage magazines are used.
- The average cost of transportation based on average distance to a centralized incineration facility ranges from $2,150.54 to $4,077.27 ("Customer Service Representative, R & R Trucking Inc.," 2014).
- Clean Harbors® is a professional waste disposal company that operates two EPA-approved incineration facilities in Aragonite, UT, and Colfax, LA, both of which currently dispose of expired PVDSs. On average, the cost at these facilities is $3.00 per flare.
- Mobile incinerators, such as the units described by the ABYC® report, incinerate one flare every 15 seconds.

- Although incineration is the most promising disposal method, other disposal methods we ultimately did not recommend were recycling, civilian burning, and dismantling, dissolving, and neutralizing.

Recommended Pilot Program

We recommend a pilot program that addresses the four key aspects of expired marine flare disposal: boater participation, collection, transportation, and destruction. Our recommended program would use:

1. Boater persuasion strategies
2. Waste transfer stations
3. Commercial transportation
4. Centralized incineration

This pilot program will have many inherent costs. In order to ensure that there is appropriate funding, we suggest that the USCG encourage a non-profit organization to pursue a grant, similar to the grant received by the CPS-ECP to help fund its project.

Any program will require boater participation. To assure public involvement, we recommend using a combination of persuasive strategies. Our data supports educating boaters using advertisements in the media, on flare packaging, and on websites. These advertisements should provide social pressures and specifically address the proper disposal of flares.

For collection sites, we recommend that boaters drop off their flares at waste transfer stations. In areas that do not have waste transfer stations, an alternative would be marina drop offs. Flare collection days, such as the educational safety equipment days held by the CPS-ECP disposal program, can be employed as another means of flare collection. All collection sites will be required to use ATF-approved magazines for storage. To simplify logistics, we recommend transportation of flares in personal vehicles from a boater's residence over relatively short distances.

We recommend that flares be carried by commercial transporters from collection sites to disposal sites, moving all obligations of legal compliance to the transporter. To address the same liability concerns as transportation, centralized incineration is our recommended means for the final destruction of expired flares.

Returning to our goal, the recommended incineration sites, such as Clean Harbors®', are approved by the Environmental Protection Agency (EPA). Also, according to our data, our

recommended process is legal. Finally, although there is cost associated with the disposal of expired flares when using Clean Harbors®-style incinerators, cost remains unavoidable in any solution and these types of incinerators best meet our other criteria; therefore, the cost is defendable. Each of these individual aspects come together to best satisfy our goal of an environmentally friendly, financially feasible, and legally sound Pyrotechnic Visual Distress Signal disposal method in which boaters will participate.

Authors

This team used a very collaborative process when writing this paper. For the writing of each chapter, except Chapter 2 and Chapter 4, the team would assign one member to type while the other three would collaboratively tell that member what to type. The role of the typist would be switched regularly so that each member spent equal time typing. For the editing of these chapters, the team would go through the chapter together with each member making edits where they saw fit. Due to their length, Chapters 2 and 4 were split up into sections with assigned authors and editors.

Chapter 2		
Section	**Author**	**Editor**
2.1	Chris	Jason
2.2	Megan	Jason
2.3	Jason	Megan
2.4	Glen and Jason	Chris
2.5	Chris and Megan	Glen
2.6	Chris	Megan
2.7	Chris, Glen, and Jason	Megan
2.8	Jason	Chris
2.9	All	All
2.10	Chris, Jason, and Megan	Glen
2.11	All	All
Chapter 4		
4.1	Glen	Chris and Megan
4.2	Chris and Megan	Jason
4.3	Chris, Jason, and Megan	Glen
4.4	All	All
4.5	Chris, Glen, and Megan	Jason

Table of Contents

Table of Figures

Table of Tables

Chapter 1: Introduction

Pyrotechnic Visual Distress Signals (PVDS), also known as flares, are a means of alerting search and rescue teams of emergency situations encountered by boaters. Due to their importance in protecting lives, the United States Coast Guard (USCG) requires all boats operating in specific conditions (Section 2.2) to carry Coast Guard approved visual distress signals (VDS) on board, many of which are flares. With a lifespan of 42 months, the number of expired flares mounts rapidly due to the infrequency of their use. This leads to the problem of PVDSs expiring at a rate that outpaces current disposal methods. From fire departments to recreational boaters, flare owners around the country are calling for a means of disposal for their PVDSs that is both environmentally friendly and financially feasible.

The United States Coast Guard was founded in 1790 with the purpose of defending the nation's oceans. One of the Coast Guard's missions is marine environmental protection. A critical aspect of this mission is to prevent chemical pollution ("USCG: Missions," 2014). The chemicals present in some flares and their potential to pollute drinking water as well as their explosive hazards combine to make safe flare disposal a high priority.

Because expired flares are labeled as hazardous materials, PVDS disposal is very difficult. The Department of Transportation (DOT) classifies most marine flares as explosive hazard class 1.4 because they present "no significant blast hazard" (GPO, 2014d). This classification restricts the allowable means of transportation for flares. Another contributor to the challenge of PVDS disposal is the solid propellant used for many flares, a chemical known as potassium perchlorate (Matthews, 2011). The Environmental Protection Agency (EPA) is currently developing a regulation on perchlorates because improper disposal could result in the contamination of drinking water (Environmental Protection Agency, 2012).

Due to these concerns, the current means of flare disposal are limited: donate to local law enforcement for training, legally ignite them, or dispose of them through commercial hazardous waste disposal facilities. However, even these disposal methods are not necessarily safe nor are they available in every community. The pace at which these methods dispose of PVDSs is considerably behind the pace that flares are expiring around the country.

The goal of this team was to recommend an environmentally friendly and financially feasible flare disposal program in which boaters were willing to participate while adhering to federal regulations. In order to achieve this goal we had a number of objectives. First, we

researched existing and past disposal methods and interviewed many companies to identify the shortcomings of these methods. Next, we established solutions to those challenges and finally, we developed a recommendation based on our research, case studies, and collected data. Our final recommendation was to create a pilot program that would use EPA-approved incineration facilities to dispose of expired flares while adhering to all federal regulations regarding transportation and storage. The success of this program is dependent on persuasive marketing to encourage boater participation. This recommendation best satisfies the criteria of our goal.

Chapter 2: Background

This chapter describes in detail the people and organizations affected by the problem of flare disposal presented in this project. We explore the history, regulations, and composition of flares, as well as the make-up and regulations of the chemical potassium perchlorate within flares. We also describe the regulations regarding collection, transportation, and storage of PVDSs. Finally, we investigate the challenges of public outreach programs in regard to public persuasion and present nine case studies on similar initiatives.

2.1 USCG Profile and Stakeholders

Originally named Revenue Marine, the United States Coast Guard has committed itself to protecting the nation's oceans and environment since 1790 ("USCG: Missions," 2014). In order to ensure the safety of American boaters, the USCG has imposed safety protocols on board private and commercial vessels. One of these requirements includes a mandate stating the necessity of unexpired VDSs on certain vessels (BoatUS, 2012). Boaters commonly choose flares to satisfy this requirement. While this addresses the USCG's mission to protect American mariners, flares' inherent hazards to the environment and the necessity for them to be replaced regularly, typically 42 months after the date of manufacturing, poses a new problem for the USCG.

Among those interested in seeing a solution to this problem are a diverse set of stakeholders, including recreational boaters, flare manufacturers and retailers, the USCG, and waste disposal companies. Since flare-owning boaters use these visual distress signals in emergency situations, they will likely be the most concerned. Flare manufactures also have an interest in flare disposal; many feel that product stewardship is important for products that have known disposal concerns. Furthermore, because marine flares need to be replaced often, the lack of a proper disposal method leads to an inevitable build-up of expired flares that are a hazard to both the environment and the safety of boaters.

2.2 Pyrotechnic Visual Distress Signal Requirements

The bright light emitted by flares makes them extremely useful for attracting the attention of others. Flares can easily be used in a wide variety of environments; this versatility makes them extremely valuable in a large range of applications. Basic uses include: signaling distress, marking hazards on the road (road flares), and marking the location of lifesaving equipment in

the event of an emergency. While in general all flares work on similar principles, some have specializations for different applications such as road, marine, and aerial environments.

Flare combustibility and the fuel that makes them burn brightly even in environments with little or no oxygen, while necessary, also define the hazards of stockpiling expired flares. Expired flares stored or disposed of improperly pose the risk of deflagration in addition to the potential risk of contaminating nearby bodies of water. For the Coast Guard, this steadily growing problem impacts the users of marine flares such as boaters and emergency services because it threatens the environment and all those whose water supply could be affected. A solution will provide boaters and marine emergency services a means of proper disposal for expired flares as well as a substantial reduction to the risk of water contamination (Orion Safety Products).

The boating community continues to use modernized versions of the original flares that were first patented in 1859. The USCG has developed regulations for vessels in the United States regarding carrying flares (Drachman, 2002). Today, the USCG requires all vessels operating within United States coastal waters, the Great Lakes, territorial seas, and any body of water where the waterway is more than two nautical miles wide to carry VDSs. Certain vessels including recreational boats less than 16 feet in length, boats participating in organized events, open sailboats less than 26 feet in length that are not equipped with propulsion machinery, and manually propelled boats are not required to carry day signals but must carry night signals when operating after sunset or before sunrise. Boats that carry PVDSs to meet their visual distress signal requirement must carry a minimum of three signals which are Coast Guard approved for both day and night use ("A Boater's Guide to the Federal Requirements for Recreational Boats and Safety Tips," 2010).

USCG approved flares include both aerial and handheld pyrotechnic red flares, handheld and floating pyrotechnic orange smoke, and flare launchers. Expired flares may be carried for backup but they may not be the only flares on board ("A Boater's Guide to the Federal Requirements for Recreational Boats and Safety Tips," 2010).

2.3 Chemical and Material Composition of Flares

The main components of flares are strontium nitrate, potassium perchlorate or potassium nitrate, and magnesium. The strontium nitrate provides the color of the flare, the potassium perchlorate or potassium nitrate acts as a powerful oxidizer that makes the strontium burn

quickly, and the magnesium gives the energy for a fast combustion ("Marine Expired Flares Disposal Problem in California," 2011). Some of the flare components degrade faster than others. Over time, the chemicals within a flare can deteriorate leading to limited burn time or altitude, a dimmer burn, difficulty of ignition, or the potential to not ignite at all (BoatUS, 2012).

Although all components of flares are instrumental in a flare's ability to work properly, flares containing potassium perchlorate are especially significant for our work because of their potential chemical hazards. Perchlorate can be used in many applications as an oxidizer for explosives such as missiles, rocket fuel, and PVDSs (Urbansky & Schock, 1999). Oxidizers are important because they allow fires, explosions, or other chemical processes to take place without an external oxygen source. Potassium perchlorate is the compound used in some flares as an oxidizer for the burn (Urbansky, 1998). It is used in explosives because it provides more oxygen and is more stable than alternatives such as potassium chlorate; resulting in a more effective and safer option (Skinner, 1920).

Due to their chemical composition, flares have been labeled as class 1.4 G and 1.4 S explosives. A class 1.4 G explosive is one that "contains a pyrotechnic substance" and presents a "minor explosion hazard;" whereas a 1.4 S explosive is one that has a limited hazardous effects and will not prohibit any emergency response efforts near the 1.4 S device (GPO, 2014b, 2014c).

2.4 Health Hazards and Remediation of Perchlorate

Perchlorate was initially brought to the attention of the EPA as a potential hazard in 1985. Since then, the EPA has conducted numerous studies to test the validity of this assertion. In 2008, the EPA made the decision not to regulate perchlorate citing that the amount of perchlorate found in the nation's water systems was not high enough for it to be considered a risk to Americans. In 2009, the EPA, in collaboration with the Nuclear Regulatory Commission (NRC), announced that 15 parts per billion of perchlorate in water should be used as a reference level for safe amounts of perchlorate (Stephenson, 2010).

Although the EPA has yet to regulate perchlorate, many states are already doing so. California and Massachusetts are pioneers in perchlorate regulation, setting their limits in state drinking water to 6 and 2 parts per billion, respectively. In the time since these two states established these regulations in 2007 (California) and 2006 (Massachusetts), more than 10 other states have also created perchlorate regulations that range from 1 to 18 parts per billion (Stephenson, 2010).

These state restrictions have been implemented because the effects of potassium perchlorate on humans have been observed and recognized as serious health threats. Doses of potassium perchlorate produce side effects that include gastric irritation, nausea, vomiting, fever, skin rashes, lymphadenopathy, and nephrotic syndrome. Sometimes, symptoms may even include leukopenia, agranulocytosis, pancytopenia, and even fatal aplastic anemia ("POTASSIUM PERCHLORATE - National Library of Medicine HSDB Database," 2014). An EPA study in 1992 on administering perchlorate to patients with hyperthyroidism, in order to determine the effectiveness of perchlorate as a treatment, showed that doses of 0.14 milligrams per kilogram per day had no observable adverse effects. However, anything above that mark produced observable symptoms. In cases with doses of 6 milligrams per kilogram per day for periods of at least 2 months, fatal bone marrow changes were observed (Urbansky, 1998).

The most commonly observed effect of perchlorate is its influence on the thyroid gland. The California Department of Health Care Services has determined that harmful thyroid effects begin to occur at 0.049 milligrams per milliliter. Fatalities would occur at around 0.21 to 0.49 milligrams per milliliter. The perchlorate interferes with the thyroid's ability to take in iodide, resulting in a decrease in production of thyroid hormones that are needed for prenatal and postnatal growth and development (Urbansky, 1998).

The most common source of exposure to perchlorates is through consumption of drinking water. Perchlorate contaminates drinking water by leaching through soil or by being directly exposed to a decomposing device containing perchlorate. Some key contributors to the contamination of soil are devices that use perchlorates, such as flares. If the chemicals within a flare are not burned to completion or if the casing of the device deteriorates, then residual perchlorate left within casings can dissolve and then contaminate any soil it rests on. The perchlorate then leaches into the soil and into ground or surface water (Trumpolt *et al.*, 2005). Though a widespread contaminant, perchlorate levels vary widely throughout the United States (Stephenson, 2010).

Perchlorates are not easily reduced or precipitated making them difficult to remove from undesirable environments, such as drinking water. Chemical reduction of perchlorate is possible but the reactions that occur are too slow to be used in practical purification processes (Urbansky, 1998). There are many other methods of reducing perchlorate, specifically developed in an

effort to remove them from water sources. These include: activated carbon, biodegradation, membrane filtration, and ion exchange.

However, when dealing with flare disposal, incineration seems to be the most viable process. Incinerators are the most effective means of destruction and control of hazardous materials like flares (Oppelt, 1987). According to the Florida Department of Environmental Protection (FDEP), flares can be destroyed in a burn unit (McKee, 2000). Incineration must occur at temperatures above 500 degrees Fahrenheit because the potassium perchlorate in flares begins to decompose into oxygen and potassium chloride, an environmentally safer chemical, at these temperatures (Glasner & Weidenfeld, 1952).

There a few incineration methods that could be used to thermally neutralize (incinerate) flares; some of these methods include mobile units, open-burn units, and rotary kilns. Mobile incinerators, are simply incinerators that can be attached to a trailer and moved (RETCM, 2014). Rotary kiln incineration units use a combustion chamber that rotates in order to vaporize waste ("Rotary Kiln Incinerator - Design and Manufacture," 2014). This incineration unit works well when thermally neutralizing mixed industrial and hazardous waste, having variable temperature capability up to 2,012 degrees Fahrenheit. Additionally, it uses both wet and dry scrubber systems that control air pollution output ("Rotary Kiln Incineration Systems," 2014). Open burn incinerators, on the other hand, use pans to hold the waste material to be burned. These pans are then covered with vented grates to limit the possibility of anything leaving the incinerator unintentionally (such as exploding aerial flares). Open-burn incinerators can burn waste in approximately 15 to 20 minutes and then cool off for an additional hour before further handling takes place. This method does not utilize an air filtration system; gases from the burn go directly into the air.

When using any incineration method, the waste ash will need to be tested through a Toxicity Characteristic Leaching Procedure (TCLP). The TCLP checks to see if any hazardous material is left in the ash. Depending on the outcome of the TCLP, the ash is shipped to a specialized disposal facility and stored properly (Treleaven, 2014).

2.5 Commercial Transportation of PVDSs

Although private transportation of flares is mostly unregulated, commercial transportation of hazardous materials, such as flares, is regulated by the DOT and the Pipeline and Hazardous Materials Safety Administration (PHMSA). Many potential flare disposal

solutions require transport of PVDSs to centralized disposal facilities (Nicklous, 2014). The DOT's transportation regulations are an important constraint in developing a disposal method.

Fireworks use many of the same chemicals and fall into similar explosive categories as PVDSs (1.4 G). Therefore, they provide a relevant example of transportation regulations. PHMSA and the DOT state that a person cannot offer to transport explosive fireworks without proper approval. An explosives (EX) approval must be issued for transportation of hazardous materials and explosives, allowing commercialized transportation around the United States. These approvals provide shipping names, hazard classes, UN classification numbers, EX approval numbers, and UN packaging specification markings must be placed on the packaging (PHMSA, 2012).

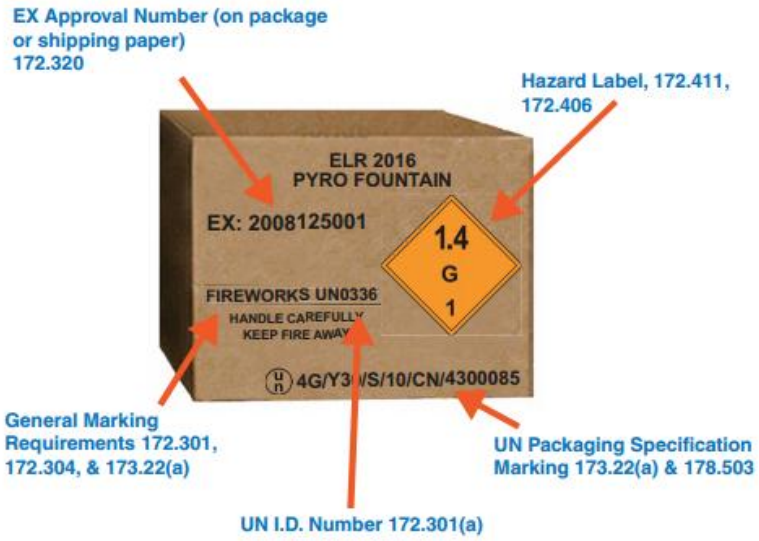

Figure 1: Packaging Example (PHMSA, 2012)

In addition to the packaging, specific shipping papers are also required. These papers must include: packing group, hazard class, shipping name, UN number, EX number, emergency phone numbers, the number of packages, and for Class 1 materials (which includes flares) the quantity in the form of net weight (PHMSA, 2012). Figure 1 shows an example of properly packaged 1.4 G category devices.

There are also weight restrictions on transportation of flares by aircraft and rail. Transportation by cargo aircraft under explosive category 1.4 S must not exceed 100 kilograms

and under explosive category 1.4 G must not exceed 75 kilograms. Transportation by passenger aircraft or by rail under explosive category 1.4 S must not exceed 25 kilograms and it is forbidden for explosive category 1.4 G (GPO, 2014a).

2.6 Storage of PVDSs

The cost to transport flares becomes cheaper when there are more flares within a shipment. Because it is not cost effective to ship small quantities of flares, collection facilities will need to be established to amass expired PVDSs prior to shipment. Storage of explosives is not trivial and is regulated by the Bureau of Alcohol, Tobacco, Firearms, and Explosives (ATF). Therefore, creating a recommendation that abided by ATF regulations was crucial to a successful disposal method (GPO, 2014e)

The ATF and DOT have different explosive classification systems; while the DOT classifies explosives as 1.1, 1.2, 1.3, etc., the ATF only has three explosives classifications. According to part 555 of the Code of Federal Regulations, these classifications are high explosives, low explosives, and blasting agents. PVDSs fall into the low explosives category because they may deflagrate when confined but are not able to detonate purely by means of a blasting cap and without confinement (GPO, 2014e; O'Lena, 2014). The ATF describes five different types of magazines for storages of explosives. Low explosives may be stored in type 4 magazines and must be inspected every seven days (GPO, 2014e). The ATF is very detailed in the regulations that describe how type 4 magazines must be constructed. In short, magazines may be either outdoors (as long as they are weather resistant) or indoors, generally must be constructed from masonry, and must be securely locked (GPO, 2014e). More details can be found in 27 CFR 555.210 and Appendix A.

2.7 Promoting Disposal in Society

Persuading boaters to participate in a disposal program is crucial to the success of any disposal method we suggest. A relevant example is motivating a community to recycle, an action that does not provide an immediate gain to the recycler and frequently costs them more money than generic trash disposal. Recycling is inherently similar to the problem of flare disposal. The book *Persuasion: Theory and Research* develops the difference between the resulting actions from general and specific attitudes. The author shows that persuasion toward a general attitude is more likely to produce a general action rather than a specific action (O'Keefe, 2002). For example, persuading people to recycle by saying that they should protect the

environment will likely cause them to act in a more environmentally friendly manner; however, they may not necessarily recycle. Protecting the environment is a general action, whereas recycling is a specific action. The author references a study showing that the correlation between a general attitude and a specific action is only about 0.30 whereas the correlation between a general attitude and a general action is 0.65 (O'Keefe, 2002). This correlation means that a disposal method for flares will be more successful if boaters are told specifically (through signs, advertisements, etc.) to dispose of flares rather than simply telling them to protect the ocean or environment.

An example of encouraging people to abide by set regulations and rules is the recycling of beer and soda containers. To encourage the public to properly dispose of these containers, Massachusetts and many other states enacted bottle bills. These bills increased the cost of beverages and then refunded the amount increased upon return of the container ("Municipal Benefits of an Expanded Bottle Bill," 2014). Expired flares are not entirely recyclable so this strategy could only be used to encourage boaters to bring their expired flares to a collection site without providing a means of disposing for those returned flares.

Another example of promoting disposal appears with electronic waste (e-waste). A study in 2006 in California surveyed a stratified representation of Californians. A mail survey was sent to 3000 households in six randomly selected counties (three in northern and three in southern California). Of the 3000 surveys mailed, 357 were returned with valid responses. According to the report this response rate is on par with other mail surveys of this nature. Although the responses were considered to be biased, the report claimed that two key observations can still be drawn from the data. The first is that convenience and familiarity with recycling are two of the most important factors in a person's willingness to recycle e-waste. Survey results showed that people who lived five miles or more away from an e-waste collection point were less likely to recycle than people living within five miles of a collection facility. The study's second observation is that people who know about household recycling (glass, paper, and bottles) are more likely to recycle e-waste (Saphores, Nixon, Ogunseitan, & Shapiro, 2006). The report's suggestions for enhancing participation of e-waste recycling include:

1. Make recycling more convenient by creating more recycling plants. Start by adding collection points in areas that already have curbside recycling pickup programs, as areas with these programs have people who are more likely to recycle e-waste.

2. Partner with retail establishments and persuade them to collect e-waste. Those retailers would then have a reason to convince manufacturers to design more environmentally friendly products.

The study concluded that people age 35-65 were more likely to recycle and that both men and people without a college education were less likely to recycle. The authors suggested initiating recycling education programs that target young adults, especially young men at the high school level. They also suggested that increasing the amount of curbside recycling programs would enhance e-waste recycling rates among older citizens (Saphores *et al*., 2006).

2.8 Finding Solutions with the Community in Mind

According to Ortwin Renn and his colleagues there are three components that should be used when finding solutions to environmental decision-making in communities. The first component in this process is finding the concern and identifying the criteria for a solution. This is the responsibility of the stakeholders: boaters, USCG, environmentalists, etc. (Renn, Webler, Rakel, Dienel, & Johnson, 1993).

The second component is recognizing and measuring the impact of the possible solutions. In this component, the criteria that are created by the stakeholders are used by experts to create rules that will be used to measure and rate the potential solutions. Once these rules are established, solutions are brainstormed by a research team through interviews of selected stakeholders and an examination of any "political precedents" that exist. After a list of solutions is established, a group of experts with diverse expertise and belief systems judges each of the proposed solutions using the aforementioned rules. This group of experts reviews and synthesizes all proposed solutions while making their opinions and justifications of those opinions known to people outside of the group. In our context, the group of experts would include representatives of flare manufacturers, the USCG, the EPA, the DOT, the ATF, and waste disposal companies.

The third component uses a model created by Peter Dienel in the 1970s and consists of a randomly selected panel of citizens to evaluate all of the potential solutions. In this scenario, the randomly selected citizen group is educated on all of the possible solutions through lectures, movies, the expert group's review, and so forth, in order to gain an understanding of the problem and the science behind the solutions. This model allows the citizen group to have discussions about the solutions regarding any potential consequences of the proposed solutions using each

individual's own value and belief systems as a driving factor. In turn, the group can give its recommendations for what would work best from the citizen perspective. The citizen perspective would be represented by presidents of boat and yacht clubs as well as members of the Coast Guard Auxiliary.

This three-stage process outlined by Renn, *et al.* was created under the assumption that if the approach to all solutions involved three different groups a much better solution would be created. Renn, *et al.* stated that the stakeholders are important because they know the problem the best and know what they want and need. The experts are crucial because they have the knowledge and ability to brainstorm the best possible solutions given the stakeholders' criteria. Finally, the authors recognized the citizens as important because they will likely either be the victims or beneficiaries of whatever solutions are chosen, thus making them some of the best judges of the solutions and their potential repercussions (Renn *et al.*, 1993).

2.9 Communicating Chemical Risks

Communicating chemical risks to the public is difficult and required methods will vary from case to case. Vincent Covello and Fredrick Allen from the EPA released "The Seven Cardinal rules of Risk Communication" to address this ambiguity. These rules help to set a standard for risk communication and, if followed, help to successfully communicate dangers to society. These rules are as follows:

1. "Accept and involve the public as a legitimate partner."
    - Adhere to the public's needs in any potential regulation that the public will be required to follow
    - Covello and Allen recommend that agencies and organizers understand that they are working for the public and must fully involve them in any crucial decision-making.
2. "Plan carefully and evaluate your efforts"
    - There are many different types of people so the generic group of the public is not specific enough to address everyone's needs.
3. "Listen to the public's specific concerns"
    - The EPA suggests using: "interviews, focus groups, and surveys" as excellent means to attain this information.
4. Be "honest, frank, and open."

- Honesty in communicating questions and any other inquiries will help you receive honest and detailed answers.
- Honesty is necessary when communicating the level of risk and to avoid exaggeration.

5. "Coordinate and collaborate with other credible sources."
    - One of the worst scenarios is the loss of public trust due to a source being found to be untrustworthy.
6. "Meet the needs of the media."
    - The media is generally more interested in the politics of the problem at hand but one can still take advantage of this interest as a means to communicate the problem.
    - Carefully prepare in advance "background material on complex risk issues."
7. "Speak clearly and with compassion."
    - It is important to maintain a connection with one's audience and avoid words that can make people nervous.
    - Maintain an understanding of your audience's differences and use this knowledge to further that connection and better explain the risk at hand (Covello & Allen, 1988).

Concerning the chemical aspect of our problem, the book *Chemical Risk Communication* notes, "When communicating about chemical risks, various social and psychological perception factors should be taken into consideration" (Beranek *et al*., 1988). The factors most pertinent to this subject are familiarity, effects on children, benefits, and controllability. In order to educate communities on the necessity of perchlorate disposal we will have to ensure that they are familiar with the problem at hand. One of the factors that can increase public concern is the discussion of the effects perchlorate can have on children. If members of the public have a good understanding of how easily this problem could be controlled, they will be more likely to act in an environmentally conscious manner (Beranek *et al*., 1988).

2.10 Case Studies on Technology and on Behavioral Change

To understand examples related to the problem of hazardous waste disposal, we explored several case studies in greater depth. The first two case studies document previous disposal projects and the remainder address the systemic concerns related to social change.

1. Contaminated Groundwater Study (2000)

This study at Longhorn Army Ammunition Plant (LHAAP) in Texas examines the treatment of perchlorate contaminated groundwater using a biological Fluid Bed Reactor (FBR). Using ethanol as a source carbon and an electron donor, the authors of this study found that they were able to significantly reduce perchlorate levels in their samples from 14.7 milligrams per liter to less than 0.350 milligrams per liter. Perchlorate is one of the most significant environmental hazards of flares, making this study extremely relevant to the problem of flare disposal. While this study does not tackle disposal of perchlorate containing items, it does show successful treatment of contaminated water and yields a possible path to a solution to the problem at hand. Problems with the applicability of this study include scale and cost; this solution could only be used in the form of treatment plants and not in a localized manner (Polk *et al*., 2000). While this case study only proposes a large-scale perchlorate treatment plant, this does not rule out the possibility of small-scale options.

2. *In Situ* Perchlorate Degradation (2000)

This study further explores perchlorate-respiring microorganisms (PRMs) and reducing perchlorate levels. Logan, Zhang, Wu and Unz at the Pennsylvania State University Pennsylvania were able to lower the concentration of perchlorate to the point that it would not be detectable. The authors were able to use lactate, produced through hydrolysis, to grow PRMs after first acclimating them to the lactate environment. PRM cells were found to grow rapidly in the lactate substrate with doubling times of 9 hours (Logan, Zhang, Wu, Unz, & Koenigsberg, 2000). This study discussed a means of increasing growth rate of PRMs to improve applicability to perchlorate reduction.

3. American Boat and Yacht Council Grant Final Report: Washington State (2003)

In 2003, the American Boat and Yacht Council's (ABYC®) final grant report included a detailed description of the "Retire them, don't fire them" campaign that was run by Orion® Marine Products (now Orion® Safety Products). In this program consumers brought expired flares to Coast Guard stations in Oregon and Washington. Coupons for ten percent off the purchase of new marine flares were used as an incentive to get boaters to bring their flares to these locations. The Coast Guard and Orion® Marine Products found this campaign necessary due to the high expense of false distress calls resulting from boaters disposing of flares by igniting them. In 1998, the Thirteenth District spent approximately two million dollars responding to false distress calls. Fifty-nine percent of those distress calls were related to flare

sightings and, of those cases, 98 percent were false alarms (Adey, 2003). The high expenses associated with false distress calls prove the importance of finding a proper disposal method for flares.

4. Promoting Mercury Safety Awareness (2007)

Shimshack, Ward, and Beatty conducted a study of the effects of a public health advisory on the community's purchase of fish that was known to contain methylmercury. The study found that there was a significant decrease in the purchase of canned fish due to a methylmercury advisory from the Food and Drug Administration (FDA). The highest response was from college educated persons and parents with young or nursing children. Access to information was limited to people who read the newspaper or advertisement. The overall conclusion of the study was that the advisory only reduced purchasing habits of consumers when they were well informed of the risks and hazards and had a valid reason to avoid the hazard (Shimshack, Ward, & Beatty, 2007). This case closely parallels our need to address the social impact of public awareness because potassium perchlorate could contaminate people's drinking water and cause adverse health effects if disposed of improperly.

5. Consumer Recycling Influences (2013)

David Treumann and Jonna Holland studied consumer behavior regarding compact fluorescent lamps (CFLs) and their possible effects upon the environment. Through surveys, Treumann and Holland found that convenience was a major concern in recycling: "Important policy implications result from the finding that the number of people who would 'always or usually' recycle CFLs increased to 90% by enhancing the convenience of recycling" (Treumann & Holland, 2013). With this in mind, developing a solution that is convenient for flare owners is extremely important and will yield higher proper disposal rates (Treumann & Holland, 2013). This closely parallels the study by Saphores *et al.* discussing convenience as previously stated in Section 2.7.

6. Increasing Community Recycling with Persuasive Communication and Public Commitment (1986)

A study run by the Boy Scouts of America shows that recycling can be encouraged through persuasive communication and public commitment. This study used 201 households that did not recycle and gave them one of three treatments: a general persuasive statement in writing, a statement of responsibility to their community, or both. They also used a control group of 132 homes that received no communication or statement of public commitment. The

households' habits were observed for six weeks and the study found that there was no notable change in the control group; however, the study claimed significant increases in recycling in the treated subjects. Both persuasive statements and statements of public commitment were equally effective (Burn & Oskamp, 1986). This study shows that in order to persuade boaters to participate, we should use advertisements of the disposal program that portray boater's responsibility to society and try to generally encourage boaters to dispose of flares properly.

7. The Effects of Behavior and Attitudes on Drop-Off Recycling Activities (2008)

Another study examined behavior and attitudes of citizens towards a drop-off recycling location. The authors claimed the success of a recycling program depends on household participation and sorting activities. Also, they found that "recycling behavior was mainly influenced by cost of recycling, convenience of available recycling infrastructure and programs, the extent of environment related awareness and knowledge, attitudes towards recycling, social norms and external pressures, and household socioeconomic status" (Sidique, Lupi, & Joshi, 2008).

These authors collected data from 356 in-person interviews at eight drop-off recycling sites around Lansing, Michigan. The factors that negatively influenced recycling behavior included distance to the recycling location, sorting time, and the respondent being employed full-time. The study found that each time the round-trip distance from an individual's home to the site increased by one mile, the expected number of visits decreased by 1%. Each one minute increase in sorting time reduced the expected number of site visits by 3.7%. Also, people employed full-time were less likely to spend time on recycling activities when compared to people who were employed part-time or were unemployed. The study also found that "location, recycling convenience, familiarity with recycling, and social pressure are all important drivers of recycling behavior" (Sidique *et al*., 2008).

8. Survey and Analysis of Consumers' Behavior of Waste Mobile Phone Recycling in China (2011)

A survey study presented in the Journal of Cleaner Production conducted by Yin *et al.* examined waste mobile phone recycling behavior in China. The authors sent 1,100 surveys to people living in four regions of China and 1,035 usable surveys were returned, a 94.1 percent yield. Through these surveys it was concluded that the creation of laws and regulations to manage electronic waste recycling was not enough to get consumers to recycle their old mobile devices. They found that consumers would have to be encouraged to participate in any mobile

device recycling program. The study identified six ways in which consumers could deal with waste mobile phones; however, 47.1% of the respondents claimed that they kept waste mobile phone and stored them in their home. Yin *et al.* also found that most of the waste phones could not effectively be recycled which leads to environmental hazards and concerns.

Lastly, the study found that consumers were only willing to pay for 0 to 5% of the recycling cost of mobile phones. The study suggests that willingness to pay is based on region, education level, and monthly income of the consumer, with people in areas that are well developed, have higher levels of education, and higher monthly incomes being more likely to recycle their waste mobile phones. The study then recommended that many stakeholders should be involved in the recycling process including the government, producers, phone carriers, recovery operators, and consumers. Yin *et al.* also recommended that the government and producers share the responsibility of recycling due to the low willingness to pay for recycling exhibited by consumers. They suggested that improving educational programs and using publicity activities that can improve public environmental awareness might make it easier to convince consumers to pay more for recycling. Lastly, this recycle payment can be organized either through a prepaid deposit or an embedded fee at the point of sales (Yin, Gao, & Xu, 2011). Cultural differences between the United States and China may cause different results if the study had taken place in the US.

9. Hotel Case Study: Peer Pressure's Impact on the Environment (2008)

A case study that examines using social pressures to influence hotel guests to reuse towels is highly relevant to flare disposal. In this study conducted by Noah Goldstein, Associate Professor of Management and Organizations at the University of California, Los Angeles, two different hotel signs were created. The first was a conventional sign asking hotel guests to reuse towels in order to be environmentally friendly. The second sign said that guests should reuse towels because most of the guests also reused towels. The study found that the second sign worked 25% better than the first sign (Krakovsky, 2008).

Another iteration of this study changed the second sign to say that the people who previously stayed in a guest's specific hotel room reused their towel. It was found that this social norm message worked even better than the first one (Krakovsky, 2008).

The study also suggests that hotels will lose less money if towels are reused because the hotel will not have to wash as many towels. This leads some people to believe that there should

be some sort of monetary incentive to guests who reuse towels. Not only does this suggestion create a logistical problem of figuring out when a guest reuses towels but Goldstein also suggested that the monetary incentive might "backfire" (Krakovsky, 2008).

A monetary incentive may not work if the "motivation crowding" theory applies. This theory suggests that "monetary incentives push away the drive to do things for other reasons" (Krakovsky, 2008). According Uri Gneezy, an economist at the University of San Diego, this behavioral theory is confirmed, for example, by a study at an Israeli day center that decided to fine parents 10 shekels (approximately $3) for picking up their children late. Adding this fine lead to more late pick-ups because parents seemed to regard the fee as the cost of being late. Turning back to the hotel case, Gneezy conjectured that guests might think, "For a dollar, I might as well get fresh towels" (Krakovsky, 2008). Gneezy concludes that it would be best for hotels to keep monetary incentives out of the program (Krakovsky, 2008).

Chapter 3: Methodology

This chapter discusses the course of action taken to reach our goal of developing a final recommendation for an environmentally friendly and financially feasible flare disposal program that boaters would be willing to participate in while adhering to federal regulations. We met the following objectives in developing this recommendation:

1. Researched and developed a thorough understanding of existing and past disposal methods and their individual merits and shortcomings;
2. Developed solutions to the shortcomings of the disposal strategies researched in Objective 1;
3. Developed a recommendation based on our research, case studies, and collected data.

3.1: Objective 1: Research Existing and Past Disposal Methods

We contacted Orion®, the leading manufacturer of marine flares in the United States, to conduct interviews regarding flare composition and perchlorate disposal. The team interviewed Orion®'s Vice President of Sales, Robert Defonte. From the interviews with Mr. Defonte, we collected information concerning Orion®'s past experiences with the disposal of marine flares including those that contained potassium perchlorate. The questions asked and interview summary are located in Appendix B.

To help prevent environmental issues from arising through the use of incinerators to dispose of flares, we interviewed Charles Treleaven from Clean Harbors® and Mark Katrichak from Pacific Blasting Co. Both disposal companies currently dispose of flares using thermal conversion units, commonly called incinerators. Mr. Treleaven gave us a better understanding of EPA approved incineration and the pollutants found in the ash of burned flares. The questions and summary from Mr. Treleaven's interview are shown in Appendix C and Mr. Katrichak's are in Appendix D.

The ABYC® and the FDEP both unsuccessfully experimented with incineration methods for the disposal of marine flares. We examined the ABYC®'s project report and then spoke with ABYC® President John Adey, one of its primary authors. Additionally, the project report from the FDEP program was provided by the Coast Guard for review. Both programs were analyzed in detail and we identified the successes and weaknesses of each.

3.2: Objective 2: Develop Solutions to Shortcomings

Previous disposal methods discussed in Objective 1 revealed that one of the roadblocks for the disposal process was transportation. We interviewed Bill Pollock, Program Manager for Alameda County Household Hazardous Waste, on the collection of expired PVDSs. Mr. Pollock has experience properly shipping and handling flares. The questions and summary from his interview can be found in Appendix E. We then interviewed Joseph Nicklous, Chief of Sciences in the Engineering and Research Division at PHMSA in the Office of Hazardous Materials and Safety within the DOT, to determine the regulations created by the DOT for the commercial transportation of explosives. The questions and summary from Joseph Nicklous' interview can be found in Appendix F.

Through our interview with Mr. Treleaven, we found that Clean Harbors® has contracted a trucking company to deliver expired flares to their disposal facilities, R & R Trucking Inc. In order to fully understand the transportation process we interviewed a representative from R & R. Questions asked during the interview and a summary can be found in Appendix G. We also called United Parcel Service (UPS) to determine the transportation restrictions and costs associated with shipping from a parcel service.

During our interview with Mr. Nicklous from the DOT, he brought up the important topic of flare storage and how flares will inevitably need to be stored prior to disposal. Through emails, the Program Manager of the Explosives Industry Programs Branch of the ATF, Michael O'Lena, clarified the regulations on storage facilities for explosive materials. Documentation of our emails with Michael O'Lena's can be found in Appendix H.

In order to gather more information regarding incineration, we asked Mr. Treleaven questions regarding the costs and processes of one of Clean Harbors®' centralized incineration facilities. In order to find more information about the capacity and burn time of mobile incinerators, we interviewed John Simonsen, CEO of Datrex, Inc. Datrex is one of the main suppliers of marine safety equipment (Datrex, 2012). The questions and summary from Mr. Simonsen's interview can be found in Appendix I.

The ABYC® grant report discussed the costs associated with buying new mobile incinerators. Another important aspect of using any type of incinerator to dispose of flares is the training of personnel to operate the incinerators and determining the liability associated with this as discussed by Mr. Defonte. Additionally, we talked to Mr. Defonte about the possibility of

recycling flares and learned the process behind Orion®'s recycling of rejected flares. Recycling of flares could allow for less material to be wasted. We also contacted Mr. Katrichak to determine how his company recycled certain components of expired flares.

Although incineration became the focus of this project, we found a few other methods of flare disposal that needed consideration. One disposal method we researched was civilian burning of flares. Since this method is recommended for handheld flares on Orion®'s website, during our interview with Mr. Defonte we discussed this method. Another alternative to incineration could be dismantling, dissolving, and neutralizing flares. To enhance the knowledge we gained through the Polk case study, Section 2.10, we asked Mr. Defonte about this disposal option for expired flares (Appendix B).

3.3: Objective 3: Recommending an Ideal Solution

In order to recommend an ideal solution for PVDS disposal, there were four criteria that had to be addressed: willing boater participation, environmental friendliness, financial feasibility, and legality. We made recommendations to the USCG based on all of the data that we received and collected.

Using survey data from the FDEP study, we were able to gain an understanding of boater disposal behavior. The team created a one-question poll that was distributed to boaters to identify current means of disposal within the boating community. This poll and its results can be found in Appendix J. These poll results, along with the survey data from Sirius Signal and the FDEP study, gave us an idea of the gravity of the problem of flare disposal. In order to learn about the willingness of boaters to dispose of their flares, we researched the project reports of a successful flare disposal program run by the Canadian Power and Sails Squadrons in collaboration with Transport Canada and CIL/Orion®.

Knowing how to encourage boaters to dispose of flares is extremely important. To gain this knowledge we examined a number of case studies. The case studies in Section 2.10, excluding the first two case studies, gave us an understanding of how we can properly motivate boaters to dispose of expired flares and allowed us to make an informed recommendation to the Coast Guard on the best disposal method for flares.

Chapter 4: Findings

The following section includes a comprehensive summary and analysis of the data that we collected. A complete solution to the problem of PVDS disposal must include boater participation through the accumulation of PVDSs prior to shipment, transportation from collection sites to disposal facilities, and disposal. We collected data on these aspects through interviews and emails with experts, collection of data reports, and review of literature.

4.1 Boaters' Attitudes towards Disposal

In 1999, a team from the FDEP conducted a study with the goal of developing recommendations for the disposal of PVDSs. In order to better understand actual boater disposal behavior, the team surveyed a sample of the 60,901 recreational boaters in Florida's southeast district. The FDEP study did not provide the number of response it received (McKee, 2000). Table 1 shows the FDEP's results of the survey.

Boaters Surveyed	Disposal Method for Flares
38.5%	Throw them in the trash
33.6%	Keep them stored
18.9%	Shoot them off/Throw in the water
5.0%	Give them to the fire department
4.0%	Take them to a hazardous household waste collection center

Table 1: FDEP Survey Results (McKee, 2000)

The data in Table 1 shows 57.4% of boaters dispose of their flares using an unsafe method (sum of "Throw them away" and "Shoot them off/Throw in the water"). This interpretation leads to three possible conclusions. First, the boaters might have been ignorant to the hazards of flares. On the other hand, some boaters may just have been unaware of any alternative means of flare disposal. Finally, some boaters may have been aware of safe disposal methods but lacked the proper motivation to participate in these methods. To further strengthen these claims, in another survey, taken by an unspecified number of participants in Palm Beach and St. Lucie counties, almost half of boaters surveyed did not know that expired flares were considered hazardous waste (McKee, 2000). These problems of education and motivation need to be addressed as part of a comprehensive solution to the problem of disposing of expired flares.

A major component of implementing any PVDS disposal method will be to alert the boating public to the new disposal option and to motivate them to participate. In January of 2011, Sirius Signal, a company working on an alternative to flares, asked 130 recreational boaters from California who were required to carry visual distress signals on their vessels, "How do you dispose of your out of date flares?" Table 2, provided by Captain Anthony Covelli of Sirius Signals, reports survey responses to this question (Covelli, 2011).

Percentage of Boaters Surveyed	How Do You Dispose of Your Out of Date Flares?
58%	Keep them stored on board the vessel
12%	Keep them stored at home
6%	Throw expired flares overboard
12%	Throw flares in the trash
12%	Left the answer blank

Table 2: Sirius Signal Survey (Covelli, 2011)

In contrast to the survey conducted in Florida in 1999, the majority of boaters (70% from Table 2) store their flares. Informing these boaters of proper disposal methods could help motivate boaters and make any new project successful.

Additionally, a single question poll created by this team and distributed to boaters by a boating organization that requested anonymity showed results similar to those found in the FDEP and Sirius Signals surveys. These results can be seen in Table 3.

Percentage of Boaters Polled (Total Responses: 1,687)	How Do You Dispose of Your Out of Date Flares?
56.4%	I keep my expired flares in storage (at house/on boat)
8.9%	Fire off expired flares on my own.
0.4%	Throw flares overboard.
3.3%	Participate in legal burn days with Coast Guard/fire department/other.
3.1%	Take to local hazardous waste disposal day.
3.6%	Take to hazardous waste disposal site that is regularly open.
13.1%	Donate to a local public service (fire or police department, Coast Guard Auxiliary, etc.)
11.1%	Other

Table 3: Flare Disposal Poll Results (anonymous source, 2014)

As can be seen in Table 3, the majority of the 1,687 boaters who responded, 56.4%, stored their expired flares. Another 9.3% disposed of their flares using an unsafe method. Some notable comments from those polled range from safe disposal, "Take to county sheriff's office," to unsafe and illegal activity, "Hide in neighbor's trash." The full list of comments can be found in Appendix J.

In May of 2014, the Canadian Power & Sail Squadrons (CPS-ECP), working in collaboration with Transport Canada and CIL/Orion®, carried out a pilot program for the collection and disposal of expired flares (Gullick, 2014). The following information was provided by Joseph Gatfield, Chief Commander of the CPS-ECP. According to Mr. Gatfield, the CPS-ECP received a grant of $31,890 from Transport Canada accounting for 75% of the costs to run the collection program. The final 25% was funded directly by the CPS-ECP. Using this grant money, the CPS-ECP hosted educational safety equipment days during which boaters could drop off their expired flares. Articles advertising the events were posted on the websites of numerous boat and yacht groups with undisclosed diffusion into the community. These articles informed boaters of the events and publicized the opportunity to drop off expired flares free of charge, motivating boaters to participate. Ten of these safety equipment days were held in nine districts, each of which hosted one or two events from May 30th to August 16th. In these

districts, flare retailers were used as the collection points (Gullick, 2014). Table 4 shows the number of flares collected at each location.

Date	Squadron / District	Retailer	Number of Flares Turned in
May 30 & 31	York East	The Rigging Shoppe	2,450
June 7	Alderney & Halifax	The Binnacle	716
June 13	Nanaimo	The Harbour Chandler	837
June 28	Windsor/Western Ontario	Happy Days Boat Centre	689
July 5	Montreal/St Lawrence	L'entrepot Marin	250
July 9	London	Xtreme Marine	455
July 19	Vancouver	Steveston Marine	1,808
Aug 7	York East	The Rigging Shoppe	1,796
Aug 16	Peterborough	Paris Marine	177
Aug 16	Kelowna	Dockside Marine	131
Collected After Events	NA	NA	1,118
Total			**10,427**

Table 4: CPS-ECP Data (Gullick, 2014)

As shown by Table 4, the total number of flares collected from the 11 safety equipment days was 9,309. Also, the program received an additional 1,118 flares after the program ended, bringing the total number of collected flares to 10,427. This final surge brought the program over its goal of collecting 10,000 expired flares (Gullick, 2014).

A disposal awareness campaign would be most effective if it incorporated many of the strategies described in the case studies found in Section 2.7 and Section 2.10. These strategies should be used to specifically target boaters' sense of responsibility to their community for proper disposal of flares (Burn & Oskamp, 1986). Advertisements could focus on convenience and social pressures.

An advertisement that shows convenience could portray low cost, close proximity, and ease of disposal. According to a case study in Section 2.10, people would only be willing to pay 0-5% of the recycling costs (Yin *et al.*, 2011). Another study in Section 2.10 found that each time the roundtrip distance from an individual's home to the disposal site increased by one mile,

the expected number of visits decreased by 1%. The same study found that each one minute increase in sorting time reduced the expected number of site visits by 3.7% (Sidique *et al*., 2008). The sorting time can be directly related to the amount of time individuals would spend at a collection center dropping off their flares.

Yet another case study, found in Section 2.10, showed that using the social pressure of telling hotel guests that most people reuse their towels, when staying at a hotel, resulted in 25% better results than only citing the environmental concerns of wasting towels. Also, this study mentioned that monetary incentives not only distract consumers from any environmental concerns, they can also work against the cause by making people less likely to participate in a program (Krakovsky, 2014).

4.2 Collection and Storage

One option for the collection of flares from boaters is centralized collection facilities within each boating community. Ideally, these locations would be waste transfer stations in areas where boaters would operate their recreational vessels. These facilities would act as a network where flares could be properly separated, packaged, and stored prior to shipment. An interview with Bill Pollock (Appendix E), Program Manager for the Alameda County Household Hazardous Waste, revealed that Alameda County had collected flares in the past and has experience properly shipping and handling flares. Mr. Pollock mentioned that shipping was quite expensive (about double the cost of the flare itself) if shipped in small quantities. While Mr. Pollock stated that Alameda County Household Hazardous Waste would be happy to take the responsibility of packaging and sorting PVDS from non-PVDS explosives, he stated that he was not aware of many disposal sites to ship to (Pollock, 2014).

In areas where centralized collection at waste transfer facilities is not possible, a program like the Clean Marinas program in Florida could act as a supplement. Many less populous areas will likely not have waste transfer facilities within easy driving distance, making collection there impractical. The Clean Marinas program in Florida uses marinas along the coast as collection points for flares. These marinas pledge to make "all reasonable efforts to complete the Clean Marina … Action Plan" (CMP, 2012). The Clean Marinas Action Plan lists several actions that are generally accepted as being environmentally responsible as well as actions to market and encourage this behavior. Among these actions is the collection of flares and other hazardous waste for disposal. Harbormasters at marinas are encouraged to post signs regarding proper

disposal, organize flare collection, and bring flares to disposal locations (CMAP, 2007). A collection method like this would prevent individuals from making long drives to waste disposal plants with only a few flares. Instead, many flares would be taken at once when the storage container at the marina became full.

Flares will inevitably need to be stored prior to disposal. The ATF regulates the storage of explosives. Michael O'Lena (Appendix H), Program Manager of the Explosives Industry Programs Branch of the ATF, explained that flares are classified as "low explosives" by the ATF, meaning they are required to be stored in at least a type 4 magazine (O'Lena, 2014). (The relevant regulations state, "[Low explosives include] explosive materials which can be caused to deflagrate when confined" (GPO, 2014e)). Such containers would need to be purchased although Special Explosive Device exemptions are possible (O'Lena, 2014). More information regarding the requirements for ATF-approved type 4 magazines can be found in Section 2.6 and Appendix A.

4.3 Transportation

Any flare disposal program will most likely require commercial transportation of flares to a centralized collection center or disposal location. Our team conducted an in-person interview with Joseph Nicklous, Chief of Sciences in the Engineering and Research Division at PHMSA in the Office of Hazardous Materials and Safety within the DOT. According to Mr. Nicklous (Appendix F), flare owners can privately transport any of their own flares to a centralized collection center or disposal location. In order to address the commercial transportation regulations, Mr. Nicklous said that flares fall under explosive categories 1.4 G and 1.4 S and all regulations regarding these categories are in 49 CFR 172.101 (2014) under the hazardous materials description "cartridges, signal" (GPO, 2014a; Nicklous, 2014). Also, in order to commercially transport flares, a company must have special permits that allows them to transport 1.4 G and 1.4 S category explosives (Nicklous, 2014). These permits can be obtained through an application process. Further details and regulations on transportation of flares are included in Section 2.5. Commercialized transportation of flares is legal and can be done following all regulations with proper permits and packaging; however, there are additional costs associated with moving class 1.4 G and 1.4 S explosives. This makes finding adequate funding paramount in reaching a successful flare disposal method.

Clean Harbors®, a company specializing in energy, environmental, and industrial services, owns two facilities that have the capability of incinerating flares. The Colfax Facility located in Colfax, Louisiana, and the Aragonite Incineration Facility in Dugway, Utah, are capable of incinerating flares. In an interview with Charles Treleaven, a sales specialist at Clean Harbors®, we found that Clean Harbors® uses third-party trucking companies to transport flares. Clean Harbors® has contracts with R & R Trucking Inc. and Tristate that stipulate a $3.50 fee per loaded mile for transportation of flares from a customer to one of Clean Harbor's incineration facilities (Treleaven, 2014). As shown in Table 5 it is in Clean Harbor's best interests to transport a minimum of 7,500 pounds of cargo per load at its contracted rate.

Through a call to an R & R customer service representative (Appendix G), we learned that a loaded truck cannot exceed 42,000 pounds of cargo ("Customer Service Representative, R & R Trucking Inc.," 2014). As an alternative to contracted transportation, the approximate charge for non-contracted shipment of flares, based on the weight and distance that the shipment travels, is shown in Table 5. This cost was based on R & R's tariff for non-contracted transportation of class 1.4 explosives from Portland, Maine, to Colfax, Louisiana. Although the exact numbers change depending on the starting and ending locations of the shipment, these numbers are acceptable for cost estimates because it was suggested by the R & R representative that they do not change much except when operating in remote areas of the country. We also were told that there was a gas charge that would be added on top of the shipping; at the time of contact with R & R (December 1, 2014) gas was $0.50 per mile ("Customer Service Representative, R & R Trucking Inc.," 2014).

Load in Pounds (Including Packaging)	Cost per Mile Traveled
< 1,000	$1.71
1,001 - 3,000	$2.12
3,001 - 5,000	$3.03
5,001 - 7,500	$3.03
7,501 - 42,000 (Full Van Rate)	$3.69

Table 5: R & R Trucking Inc. Rates of Non-Contracted Transportation from Portland to Colfax ("Customer Service Representative, R & R Trucking Inc.," 2014)

We created a model of some potential transportation routes in order to see how expensive shipping flares would be based on distance. The model had the following parameters:

- Restricted to the 48 contiguous states (transporting flares from places outside of the lower 48 would need forms of transportation other than trucking)
- Starting points would be one of 39 Coast Guard Sectors and Marine Safety Units in 23 states (the Coast Guard is generally located near popular boating areas)
- The model represents 8,909,572 of the 12,013,496 (74%) registered recreational boats in 2013 ("Table 38 Recreational Vessel Registration Data By State 2012-2013," 2013)
- End location is either the Aragonite or the Colfax Clean Harbors® locations (the closer one was chosen in each instance)

We used Google Maps® to calculate the approximate distance that would need to be travelled in order to take the flares from each Coast Guard location to the nearest Clean Harbors® location. We recognized that trucks, especially those carrying explosives, may not have the same road access as an average car (the target audience of Google Maps®). Therefore, the distance travelled might be different in practice, but we believe that the numbers generated still give a usable reference.

We then calculated the average distance travelled to the Clean Harbors® facility scaled by the fraction of the boating population in each state. This scaled distance was necessary in order to ensure that our average distance traveled to the facility represented the locations from where most flares would be shipped. The scaled distance is represented by the following formula:

$$SD = \frac{\sum_i (s_i * p_i)}{b}$$

where *SD* is the scaled distance, *s* is the distance from each Coast Guard location to the appropriate Clean Harbors® facility, *p* is the number of registered recreational boats in the state in which the particular Coast Guard station is located, *b* is the total number of registered recreational boats in the 23 states that were represented in the model, and *i* is the summation index representing each summation iteration.

In the cases where there were multiple Coast Guard facilities in a state, *s* was calculated by taking the average distance needed to reach Clean Harbors®. The calculated scaled distance was about 973 miles while the un-scaled average distance was 963 miles. This information is presented in greater detail in Appendix J. Using the average distance travelled we were able to calculate the cost to transport the flares using both the Clean Harbors® contract fee of $3.50 per

loaded mile and the R & R non-contract variable fee scale discussed earlier. The final transportation costs can be found in Appendix L, and a summary of both Appendix F and G can be found in Table 6.

Starting Location	Starting State	Clean Harbors® Contract Rate ($3.50)	R&R Tariff Rates					
			Gas Cost Addition-$0.50 per mile (as of 12/1/2014)	< 1,000 lbs (~$1.71)	1,001 – 3,000 lbs (~$2.12)	3,001 - 5,000 lbs (~$2.36)	5,001 - 7,500 lbs (~$3.03)	Van Rate 7,501 - 42,000 lbs max (~$3.69)
Below are a Few Samples of the Calculations and the Final Averages								
CG Sector Hampton Roads (05-37070)	VA	4,725.00	675.00	2,983.50	3,537.00	3,861.00	4,765.50	5,656.5
Sector Puget Sound (13-37320)	WA	3,717.00	531.00	2,347.02	2,782.44	3,037.32	3,748.86	4,449.78
Sector Lake Michigan (09-37240)	WI	3,489.50	498.50	2,203.37	2,612.14	2,851.42	3,519.41	4,177.43
Averages / Totals (USD)		**3,372.74**	**481.82**	**2,129.64**	**2,524.73**	**2,756.01**	**3,401.65**	**4,037.65**
Using SD (USD)		**3,405.84**	**486.55**	**2,150.54**	**2,549.51**	**2,783.05**	**3,435.03**	**4,077.27**

Table 6: Transportation Cost Model

Finally, Table 7 shows the cost of transportation per pound for various shipment loads. These loads include the packaging, dunnage (loose packing materials for cargo protection), flares, and anything else that may be needed for transport.

Weight of Shipment (lbs)	Price Per Pound of Shipment
500	$4.30
1,000	$2.55
3,000	$0.85
5,000	$0.56
7,500	$0.46
42,000	$0.10

Table 7: Cost of Transportation per Pound ("Customer Service Representative, R & R Trucking Inc.," 2014)

The data in Table 7 shows that shipment price per pound of cargo goes down significantly when transportation weight goes up, suggesting that transportation is more economical with larger shipments of flares.

To create a relevant example of transportation cost we use the CPS-ECP program. First, taking the 10,427 flares collected and using 0.5 pounds as the average weight for a flare (shown in Appendix M), it can be determined that 5,213.5 pounds need to be transported. Assuming that the packaging weighs no more than 2,286.5 pounds, we can safely say that the shipment will fall into the 5,001-7,500 pounds non-contracted bracket stipulating a $3.03 fee per loaded mile. Taking into account the $0.50 per mile gas charge and the 973.10 mile scaled distance, it can be determined that the transportation cost would be $3,435.04 which results in $0.33 per flare. This reveals that funding will be needed in order to transport flares to a location for proper disposal, but the cost to do so is defendable based on the environmental and safety concerns that expired flares may pose when not disposed of or disposed of incorrectly.

Although transportation using a company such as R & R seemed to be the logical method of transportation for flare disposal, it was not the only option. UPS® also has the ability to transport some class one explosives; however, according to its website, UPS® transports hazardous material on a contract basis and accept non-bulk shipments as long as the material is packaged according to DOT regulation ("Hazardous Materials Service Definition," 2014). According to a personal inquiry with an employee working at the UPS® Hazardous Materials Support Center, UPS® can only ship class 1.4 S flares, which are usually handheld flares, such as Orion®'s Hand-Held Red Flare Signal. In order to ship this material UPS® adds a $28.50 fee on top of any normal shipment costs ("UPS Hazardous Materials Support Center Representative,"

2014). Doing a cost analysis using UPS® to transport expired flares is impractical due to the restriction to class 1.4 S flares, since any collection facility will undoubtedly receive flares that do not fall into this category. Cost, as well as this restriction, makes transportation by UPS® not functional for transportation from a collection facility to a disposal site; however, it could be an option for a recreational boater who only owns class 1.4 S flares and lives far away from a collection facility.

4.4 Disposal Using Incinerators

Incineration is a promising method of flare disposal and includes both centralized incineration sites and mobile incinerators. Examples of professional centralized incineration facilities are the two operated by Clean Harbors®. Both Clean Harbors® facilities, Aragonite and Colfax, hold federal permits from the EPA as well as permits from the individual state's environmental protection agency (Treleaven, 2014). Mobile incinerators are incinerators that can be transported to different flare collection locations.

1. Cost to Incinerate Flares

Much like the transportation of flares, the actual disposal of flares has an inherent cost that needs funding. According to Mr. Treleaven, Clean Harbors® charges $6.00 per gross pound of waste that is incinerated with a minimum charge of $3,000 to run the incinerator (Treleaven, 2014). Clean Harbors® has a permit that allows it to burn 350 pounds of flares per incinerator. Assuming that the average weight of a flare is about 0.5 pounds (shown in Appendix M), 700 flares can be put into an incinerator per burn (Treleaven, 2014). If only 700 flares – 350 pounds – are in need of disposal, the $3,000 minimum fee would be charged for incineration, corresponding to about $4.29 per flare.

As a more realistic example, the CPS-ECP flare disposal program collected 10,427 flares, which would equate to 5,214 pounds. With a charge of $6.00 per gross pound, the total cost to burn 5,214 pounds of flares would be $31,281.00 or about $3.00 per flare. Although using Clean Harbors®' incineration facilities comes with a cost, price is an unavoidable hurdle in any solution and these types of incinerators best meet our other goal criteria; therefore, the cost is defendable.

2. Capacity and Burn Time

A limiting factor for incineration could be the capacity and burn time of the incinerator. Our team interviewed John Simonsen (Appendix I), CEO of Datrex (a marine signal retailer), who discussed an incineration program that Datrex had run in the early 2000s to dispose of

flares. He mentioned that the incinerator at Datrex could burn multiple flares at one time. Filling the incinerator had the potential to damage it so, Mr. Simonson said, the incinerator was never run at capacity (Simonsen, 2014).

We also reviewed information from John Adey, current President of the ABYC®, which described a past incineration program using Reactive & Explosive Materials Training Corporation (REMTC) incinerators. These incinerators took approximately 15 seconds to burn each flare. He, too, also warned against filling the incinerator to capacity (Adey, 2003).

While these two previous incineration programs seemed to show capacity as a limiting factor, the incineration program run by Clean Harbors® demonstrated the efficiency that could be attained with incineration. Clean Harbors®' permit allows them to burn 700 flares in each incinerator at one time (Treleaven, 2014). Therefore, capacity restriction is not an issue if using incinerators like those utilized by Clean Harbors®.

Besides using an existing incineration facility like Clean Harbors®, another option is to set up a mobile incineration program where one incinerator (or more) would travel throughout an area collecting and disposing of flares in a trailer-hitched burn unit. According to an FDEP study completed in 2000, mobile incinerators can cost anywhere from $7,400 to $17,800 per unit (McKee, 2000). Due to this large startup cost and the likely need for multiple incinerators to handle the numbers of expired flares throughout the country, the cost associated with purchasing and operating mobile incineration units is not feasible..

3. Personnel Training and Liability

Our interview with Robert Defonte (Appendix B), Vice President of Sales at Orion® Safety Products, revealed another concern to be addressed if incineration were to be chosen as a flare disposal method. Mr. Defonte was concerned for the liability of any company operating incinerators as well as the insurance for the operating personnel. Incinerators are expensive investments for any company disposing of flares and therefore proper training of operating personnel is crucial to protect those investments. Mr. Defonte suggested that this training can be difficult and expensive and, with the inevitable hazards of burning explosives, the insurance of operators is something that must be considered (Defonte, 2014).

4. Clean Burning

Research suggests that incineration is clean in the sense that the smoke output has little adverse effect on the environment. After interviewing John Simonsen (Appendix I), we learned that the manufacturer of Datrex's flares, Nammo, had an incineration program running in Sweden in which they had tested the ashes and the smoke output from their incinerators. Mr. Simonsen stated that Datrex's incineration program in the United States was shut down because of the amount of smoke that Datrex's incinerator was releasing. He also stated that the EPA proposed the solution of a water filtration system to prevent the smoke from being released (Simonsen, 2014).

Other incineration programs, such as Pacific Blasting and Clean Harbors®, have not had problems with smoke output. Mark Katrichak (Appendix D), the Operations Coordinator at Pacific Blasting (Canada), operates incinerators without filtering the smoke (Katrichak, 2014). Also, Mr. Treleaven (Appendix C) of Clean Harbors®, stated that its open-burn incinerators did not require filtration. While Canadian environmental protection laws may be different than those in the United States, Mr. Treleaven stated that Clean Harbors®' incinerators had proper permits from the EPA and did not need to filter smoke (Treleaven, 2014).

4.5 Other Disposal Options

Besides using incinerators to dispose of expired flares we also looked into other methods including recycling, civilian burning, and dismantling, dissolving, and neutralizing flares.

1. Recycling Flares

One potential disposal method would be to recycle or repurpose old flares. From our interview with Robert Defonte from Orion® (Appendix B), we found that Orion® drilled out the casings and reused the material in the manufacturing process from flares that did not meet quality standards. Mr. Defonte cautioned that this process was not safe with expired flares as the condition of these flares would not be known, thereby posing a significant risk to any operator who would be dismantling the flare (Defonte, 2014).

Our interview with Mr. Katrichak from Pacific Blasting (Appendix D) informed us that while its operators incinerated combustible material, they would drill out the chemicals from some flares that appeared to be in good condition and were of a construction that was familiar to them. For flares that were of unfamiliar construction or poor condition, operators would incinerate the entire flare and remove and recycle the casings after the incineration was complete

(Katrichak, 2014). While recycling of the entire flare may not be practical, the casings can still be safely recovered for recycling.

2. Civilian Burning

Another possible disposal method is to have boaters ignite the flares on land in a safe area. This practice is suggested by Orion® on its website: "Ignite hand-held signal(s) flares on land in a safe area, much the same as highway flares would be ignited" (Orion Safety Products). Robert Defonte (Appendix B), Vice President of Sales at Orion® Safety Products, pointed out that it is legal to ignite handheld flares in non-emergency situations (Defonte, 2014).

The major drawback to this method is that this solution only works for handheld flares. Setting off an aerial flare is recognized as a distress signal over land or water, thus classifying this action as a false distress call. False distress calls are a Class D felony under Title 14, U.S. Code, Section 85. According to the Special Local Notice to Mariners, it is a federal crime to knowingly and willfully set off a flare with the intent of causing the Coast Guard to attempt to save lives and property when it is known that no assistance is needed ("Special Local Notice to Mariners," 2014). The notice states explicitly, "Do not fire flares in order to dispose of them. These devices are meant to signal for assistance and are not to be used as fireworks" ("Special Local Notice to Mariners," 2014).

The document notes that the Coast Guard and other local harbor marine patrols spend millions of dollars on hoax calls. A person who makes a hoax call can be made to repay the government's cost to respond to the hoax and that could amount to hundreds of thousands of dollars ("Special Local Notice to Mariners," 2014).

3. Dismantle, Dissolve, and Neutralize

Another potential flare disposal method would be to dismantle the flare, dissolve it in a chemical or biological solution, and then neutralize the solution. Upon further research we found that if a flare containing potassium perchlorate was shredded in order to dismantle it and then dissolved in a solvent to neutralize it, the chemical potassium perchlorate would be left in the solvent. Since potassium perchlorate is a hazardous chemical, development of another disposal method for the perchlorate rich solvent would need to be developed (Polk *et al*., 2000).

During our interview with Robert Defonte (Appendix B) from Orion® we asked if Orion® would dismantle the flares, dissolve them, and neutralize them. He told us that this would be a

dangerous process because shredding a flare would create heat which could cause the chemicals within the flare to ignite (Defonte, 2014).

An additional problem with neutralization of flares chemically or biologically is volume. In a case study, Section 2.10, we reported a study of the use of perchlorate-respiring microorganisms (PRMs) to remove perchlorate from contaminated water, the process required large processing plants and large volumes of contaminated fluid. These plants would encounter the same issues with transportation and boater participation that incineration would along with the added difficulty of dismantling flares (Polk *et al*., 2000).

Chapter 5: Conclusions and Recommendations

Most boaters do not dispose of flares correctly. The FDEP survey showed that only 9% of boaters properly dispose of flares. Also, the survey conducted by Sirius Signal and our poll showed that many boaters (88% and 65.7% respectively) either do not dispose of flares or do so illegally. (See Section 4.1.) These findings illustrate the severity of the problem of PVDS disposal.

We recommend a pilot program that addresses the four key aspects of expired marine flare disposal: boater participation, collection, transportation, and destruction. Our recommended program would use:

1. Boater persuasion strategies
2. Waste transfer stations
3. Commercial transportation
4. Centralized incineration

This pilot program will have many inherent costs. In order to ensure that there is appropriate funding, we suggest that the USCG encourage a non-profit organization to pursue a grant, similar to the grant received by the CPS-ECP to help fund its project.

Any program will require boater participation. To assure public involvement, we recommend using a combination of persuasive strategies. Our research supports educating boaters using advertisements in the media, on flare packaging, and on websites. These advertisements should provide social pressures and specifically address the proper disposal of flares. As referenced in the study of reusing towels in Section 2.10, social pressures are a much better motivator than citing environmental concerns alone. The same study also suggests that not only do financial incentives not work, they can even persuade consumers to ignore a suggested behavior. For these reasons, we recommend an advertising campaign that uses social pressures to motivate boaters towards disposing of their expired flares, especially social pressures that suggest most other boaters are properly disposing of their flares. Finally, in order to ensure that a final disposal method will be taken advantage of by boaters, we recommend using a focus group consisting of boat and yacht club presidents and Coast Guard Auxiliary members as outlined in Section 2.8.

For collection, we recommend that boaters drop off their flares at waste transfer stations. In areas that do not have waste transfer stations, an alternative would be marina drop offs, such

as those organized in the Clean Marinas program in Florida mentioned in Section 4.2. Flare collection days, such as the educational safety equipment days held by the Canadian Power and Sail Squadrons disposal program, can be employed as another means of flare collection. This option would help alleviate the costs associated with operating waste transfer stations that accept flares. Flare collection days would also allow many flares to be collected at one time, making transportation more simple and affordable. Regarding flare storage, Section 4.2 allows us to conclude that all collection sites will be required to use ATF-approved magazines for storage. To simplify logistics, we recommend transportation of flares in personal vehicles from a boater's residence over relatively short distances.

In order to transport the flares from waste transfer sites to disposal sites, we recommend that professional commercial transporters, such as R & R Trucking Inc. mentioned in Section 4.3, be employed. Using commercial transporters allows for a proven and effective means of transportation. This transportation method will not have trouble with DOT permitting because these transporters are already approved to accommodate the shipment of flares.

Centralized incineration is our recommended means for the final destruction of expired flares. As mentioned in previous sections, one example of a company that currently uses this method is Clean Harbors®. Clean Harbors® owns two incineration facilities; both hold federal permits from the EPA as well as permits from their individual state environmental protection agencies (Treleaven, 2014). Additionally, professional waste disposal companies already have all of the procedures in place to properly dispose of flares; this reduces additional steps that would otherwise be required to make final destruction methods work. In order to broaden the number of potential flare disposal facilities, we recommend further research on other incineration capable sites around the country.

A recent example of an effective pilot program for the collection of flares is the initiative run by the Canadian Power and Sail Squadrons. The Canadian program exceeded its goal of collecting 10,000 flares by amassing 10,427. As a result, Michael Smith, Director of the CPS-ECP, stated that the program "truly was a success" (Smith, 2014). More details on this program can be found in Section 4.1. As shown in Table 8, the reports indicated that many participants who disposed of their flares were members of the CPS-ECP. We recommend partnering with organizations with similar social status among boaters as a marketing tool.

Date	Squadron/District	Retailer	CPS-ECP Members Disposing of flares and Interviewed	People Interviewed	Percentage of CPS-ECP
May 30 & 31	York East	The Rigging Shoppe	~ 40	79	~50%
June 7	Alderney & Halifax	The Binnacle	"Many"	43	N/A
June 13	Nanaimo	The Harbour Chandler	~30	43	~70%
June 28	Windsor/Western Ontario	Happy Days Boat Centre	16	28	~57%
July 5	Montreal/St Lawrence	L'entrepot Marin	6	9	~67%
July 9	London	Xtreme Marine	6	38	~16%
July 19	Vancouver	Steveston Marine	No Report Received	N/A	N/A
Aug 7	York East	The Rigging Shoppe	No Report Received	N/A	N/A
Aug 16	Peterborough	Paris Marine	6	12	50%
Aug 16	Kelowna	Dockside Marine	No Report Received	N/A	N/A
Totals			**269**	**6,834**	**9,309**

Table 8: Percentage of CPS-ECP Members Talked to (Gullick, 2014)

As shown in Table 9, we studied numerous methods of flare disposal. We do not recommend mobile incineration because the incinerators are expensive to purchase and states would need multiple units due to their low capacity and relatively slow burn times (one flare per 15 seconds compared to 350 pounds of flares, roughly 700 flares, per 15 to 20 minutes by a Clean Harbors® incinerator). Personnel operating these units would need proper training and insurance to run each new unit. We also recommend against disassembly/recycling due to the dangers associated with the disassembly of flares in unknown conditions. Similarly, civilian ignition of flares is not recommended because ignition is dangerous due to the unpredictability of expired flares. In addition, we cannot recommend ignition because it is an incomplete solution as it is only compatible with handheld flares.

Boaters	Collection	Transportation	Disposal
Financial Incentive	Waste Transfer Stations	Private	Professional Centralized Incineration Facilities
			Mobile Incineration
Education	Marina Drop Off	Commercial Transporters	Disassembly and Recycling
			Ignite the Flares
Media Coverage	Flare Collection Days	UPS® Shipment	Throw Away

Key

Recommended Solutions	Not Recommended Solutions

Table 9: Disposal Process Options

Returning to our goal stated in Chapter 1, the recommended incineration sites, such as Clean Harbors®, are EPA approved. Also, according to our interviewees, our recommended process is legal. Finally, although there is cost associated with the disposal of expired flares when using Clean Harbors®' style incinerators, cost remains unavoidable in any solution, and these types of incinerators best meet our other criteria; therefore, the cost is defendable. Each of these individual aspects come together to best satisfy our goal of an environmentally friendly, financially feasible, and legally sound Pyrotechnic Visual Distress Signal disposal method in which boaters will participate.

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Appendices

Appendix A: ATF Regulations

All of the following regulations describe the construction and use of a type 4, ATF approved, storage magazine and can be found in 27 CFR 555 § K, 2014 (GPO, 2014e).

- Personnel must inspect the magazine at least every seven days to determine whether there was authorized or attempted entry into the magazine or if there was unauthorized removal of contents stored within the magazine.
- Outdoor magazines that store low explosives must adhere to the distance regulations

§555.219 Table of distances for storage of low explosives.

Pounds		From inhabited building distance (feet)	From public railroad and highway distance (feet)	From above ground magazine (feet)
Over	Not over			
0	1,000	75	75	50
1,000	5,000	115	115	75
5,000	10,000	150	150	100
10,000	20,000	190	190	125
20,000	30,000	215	215	145
30,000	40,000	235	235	155
40,000	50,000	250	250	165
50,000	60,000	260	260	175
60,000	70,000	270	270	185
70,000	80,000	280	280	190
80,000	90,000	295	295	195
90,000	100,000	300	300	200
100,000	200,000	375	375	250
200,000	300,000	450	450	300

shown in Table 10

Table 10: Table of Distances for Storage of Low Explosives from 27 CFR 555.219 (GPO, 2014b)

- Construction of type 4 magazines must follow all guidelines specified in 27 CFR 555.210 (2014).
- The magazine may not exceed 300,000 pounds of explosives at any time, unless otherwise approved.
- Explosive materials must be stored such that they do not come into contact with interior walls allowing for ventilation.
- Containers must be stored so markings are visible and can easily be checked during inspection.
- Unpacking or repacking explosives' containers must be done with a non-sparking object at least fifty feet from the magazine with the exception of fiberboard/nonmetal containers.

One example of a type 4 magazine is shown in Figure 2.

Figure 2: ATF Approved Type 4 Magazine

Appendix B: Orion® Interview with Robert Defonte

November 11, 2014

Questions:

1. Tell us about some of your experience with flare disposal.
2. What do you do with flares that do not meet quality standards?
3. What would be the safest way to disassemble a flare?
4. Can you repurpose expired flares?
5. Do you have production data you could send to us to give us an idea of how many flares you are producing?
6. Do you have any recommendations for flare disposal?

Answers:

1. California allowed boaters to drop off signals but there would be more than just flares in the boxes (hand grenades, explosives, etc.) Can't dispose of some of the products they dropped off. Couldn't ship them.
2. Handheld and aerial ship to disposal site or a collection point. Licensed disposal facility with trained personnel. Has a person interested in running a facility.
3. Reclaim the product from reject flares. Drill product out and reuse the chemical in defective flares. Not stored or handled separately. Simplistic manufacturing process. Very little rejects.
4. Very interested in program and how to assist and funding. Opportunity to get the product off the street.
5. Will send production data if Orion® receives proposal on Coast Guard letterhead… (Proposal sent never received production data)
6. DO NOT REPURPOSE AFTER 42 MONTHS. No idea on the weather or conditions it has been through.
7. Very dangerous to separate chemicals from flare in old flares. Not something they have looked at. How to dispose of chemical after neutralized. Still have issue of how to burn off that material.
8. INSURANCE: Who uses the incinerator? First time there is an incident or a mistake there is a problem. State provided certified technicians who hold the liability insurance.
9. Collect, ship, and get to an approved incinerator point with necessary permits

Appendix C: Clean Harbors® Interview with Charles Treleaven

November 21, 2014

Questions:

1. How do you dispose of flares?
2. Is the disposal done onsite?
3. What do you do with ash/ smoke?
4. Have the incinerators been tested?
5. Can you provide us with data on:
    a. Filtration methods?
    b. Capacity/ volume issues?
    c. Operator error/ Insurance concerns?
    d. How many flares are collected?
6. How long do you take to dispose of the flares?
7. How do you get the flares, are any flares rejected, on what basis?
8. How do you store flares prior to disposal?
9. How do the Marinas store flares before taking them to you?

Answers

1. We have two disposal facilities
    a. Aragonite, UT
    b. Colfax, LA
2. Open burn incineration: flares are put in pan and covered with grate to prevent aerials from escaping the incinerator
3. Ash is tested with TCLP test to determine toxicity and disposed of appropriately
4. TCLP: Toxicity Characteristic Leaching Procedure
5. Incinerators are not filtered
6. Licensed by EPA and LA Department of Environmental Protection
7. Diesel fuel is used to start the burn
8. Clean Harbors® collects from all around the county
9. Collection points are generally consumer facilities that call in and say they have flares and schedule a pickup
10. Customers are usually individual companies (some marinas on west coast use collection days and send in flares)

11. Transportation cost are usually $3.50 per mile and disposal is a minimum of $3,000 with $6/gross weight pound after the first $3,000 dollars
12. Flares are transported by truck in DOT approved packaging
13. Customers are allowed to provide their own transportation if they prefer
14. Uses third party for transportation of flares
15. Packaging is usually a polymer/fiber container or 55 gallon drum
16. Permit calls for up to 350 pounds per burn
17. Each burn last about 15-20 min and Clean Harbors® burns every hour
18. Does not know of any other waste disposal companies that accept flares
19. ATF storage magazines are required for collection
20. All items must be profiled so that Clean Harbors® knows what they are getting
21. They have never rejected any flares to his knowledge
22. They add anywhere from 10%-15% to the invoice, which includes both transport and disposal, to account for fuel and insurance surcharge.

Appendix D: Mark Katrichak Pacific Blasting Company (Date not recorded)

Questions:

1. Do you accept flares for disposal
2. Can you tell me about this disposal program?
3. What do you do with the ash from the incineration?
4. What do you do with smoke pollution/output?
5. Do you treat all flares the same way or are there separate procedures for handheld, aerial, and smoke flares?

Answers:

1. Yes we accept flares.
2. We use an incinerator from the Police Bomb Disposal Unit. For certain flares that are in good shape, drill out and recycle casing. Most get incinerated though.
3. Recover the casings from the ash and recycle. No problems with ash disposal
4. No problems with smoke output. Incinerate away from the public.
5. Smokes and handheld flares both burn completely and just leave metal casing behind.

Appendix E: Alameda County Household Hazardous Waste Interview with Bill Pollock

November 10, 2014

Questions:

1. Do you still accept flares?
2. What do you do with the flares after you collect them?
3. How much did shipping flares cost?
4. Where were they shipped?

Answers:

1. We only take flares from households and not businesses
2. We ship our flares to an incineration facility in Texas
3. About $500 for a five gallon container
4. Flare transportation is very expensive, have you heard of product stewardship? This is the idea that manufacturers of products with known disposal issues should be responsible for the disposal of their product.

Appendix F: Department of Transportation Interview with Joseph Nicklous, Richard D. Tarr Ph.D., and Steven W. Andrews

November 13, 2014

Questions:

1. Are there ways to make commercial transportation easier, maybe through a special permit?
2. Can Civilians transport flares without any restrictions?
3. We've been told that shipment of flares can be almost as expensive as buying a brand new package of flares, why is this?
4. Before transportation, are there any regulations stipulating the proper storage of flares?

Answers:

1. For really old fireworks you need to get a special permit, classification can be changed by permits
2. A company can design and standardize a new transportation process, submit it to DOT and potentially get a special permit
3. Using some desensitizing process could lead to a special permit that makes transportation easier
4. "Reverse logistics"
    - Program that handles a product's transportation from consumers back to the distribution facility
    - The EPA is hesitant to allow retailers to determine if a product should be considered hazardous
    - This does not apply to pyrotechnics
5. A civilian can transport his own flares
6. Permits
    - To get a special permit you need to prove that there is the same level of safety to the original regulations
7. It may be expensive to transport just a few flares, but when you have a lot it may be cheaper
8. If an organization like a Yacht club collected flares would they be considered a hazardous waste collector? May need to ask ATF about storage of flares

Appendix G: R & R Contact, Customer Service Representative

December 2, 2014

Questions:

1. What is the capacity for your trucks for flare transport?
2. What is the coast to transport flares?
3. Does R & R package the flares or are they packaged by the customer?
4. Does R & R work with waste disposal companies other than Clean Harbors®

Answers:

- 42,000 pound maximum weight for trucks (including dunnage, flares, pallets, etc.)
- Cost from Portland, ME to Colfax, LA

Weight of Total Shipment (Pounds)	Cost per Loaded Mile
Less than 1,000	$1.71
1,001 - 3,000	$2.12
3,001 - 5,000	$2.36
5,001 - 7,500	$3.03
7,501 - 42,000	$3.69

- Fuel cost changes weekly but as of 12/2/2014 it is $0.50 per mile

Appendix H: Emails with Michael O'Lena, ATF

Good Evening,
I am part of a group of Interns working with the United States Coast Guard to develop a means for pyrotechnic flare disposal. Through our research we have realized that any likely disposal method for expired marine flares will require collection facilities around the country (such as waste disposal companies) that will ship the expired pyrotechnics to a centralized processing facility that will properly dispose of them. After speaking with representatives from the DOT and with Charles Treleaven from Clean Harbors we found that collection of these flares, specifically the storage at the collection site, is likely governed by the ATF. I have been trying to find the specific regulations regarding the storage containers that would have to be used to properly store these flares and have found CFR 555. Unfortunately I am unable to find which of the three classes of explosive materials (CFR 555.202) flares fall into. Under DOT Classification, flares fall into the 1.4 explosives category. Some examples of Flare UN numbers are: UN0373 (handheld) and UN0312 (aerial).
Any help would be greatly appreciated.
Thank you,
Krzysztof Borowicz CIV
U.S. Coast Guard (CG-CVC-3)
Fishing Vessel Safety Division
(202)-372-1259
krzysztof.a.borowicz@uscg.m
(Friday, November 21, 2014 5:14 PM)

Hello Krzysztof

Generally, ATF classifies these types of pyrotechnic flares as low explosives requiring storage in at least a type 4 magazine. The specific type 4 magazine requirements can be found at 27 CFR 555.210. I've attached a magazine construction publication that gives some general guidance about the different types of magazines but doesn't contain everything. The following link will take you to our regulations: https://www.atf.gov/files/publications/download/p/atf-p-5400-7.pdf
Let me know if you need anything else.
Mike O'Lena
Program Manager
Explosives Industry Programs Branch
Bureau of Alcohol, Tobacco, Firearms and Explosives
202-648-7112
(Saturday, November 22, 2014 9:44 AM)

Mr. O'Lena,
Our research has found inconsistent adherence to these regulations, is there a minimum quantity at which these regulations apply, or do they apply as soon as collection becomes commercialized? The reason I ask is that setting up collection points for expired marine flares at marinas and harbors is an attractive option in areas where large scale hazardous waste disposal plants do not exist, but if marinas would be required to operate ATF approved storage magazines, this may deter many marinas from participating in a disposal program.
Thank you for any input on this,
Krzysztof Borowicz CIV
U.S. Coast Guard (CG-CVC-3)
Fishing Vessel Safety Division
(202)-372-1259
krzysztof.a.borowicz@uscg.mil
(Monday, December 08, 2014 9:10 AM)

Good morning Krzysztof

There isn't a minimum quantity where it becomes ATF-regulated vs not regulated. However, we have provided special explosive device (SED) exemptions to a few companies for these types of devices. The SED exemption basically exempts the device from our explosives requirements. We base those determinations, in part, on the net explosives weight and intended use. However, we don't have a list of the exempted devices because the determinations are all private letter rulings to a specific company. We generally tell people that if the device has a DOT Class 1 classification then it's ATF-regulated unless accompanied by a SED letter of exemption.

We could certainly work with marinas to figure out some sort of arrangement for storage purposes. We generally don't exempt a group of devices (e.g. 1.4 flares) as a whole. We exempt specific devices that are accompanied by MSDSs, DOT approvals, testing documents, diagrams, etc. Like I said though, I think we could work to ensure proper compliance with our regulations...without being too much of a burden.

Let me know if you need anything else.

Mike O'Lena
Program Manager
Explosives Industry Programs Branch
Bureau of Alcohol, Tobacco, Firearms and Explosives
202-648-7112
(Tuesday, December 09, 2014 3:36 AM)

Appendix I: Interview with John Simonsen, Datrex CEO

November 7, 2014

Questions:

1. What did the EPA find that was so concerning? What were the pollutants? Why was your program shut down?
2. How long had the process been operating? Did it seem successful?
3. How did you get involved with this process? Why were/are you interested in finding a solution to flare disposal? Does it have to do with your company?
4. Do you know how the incinerators were different? (aerial vs handheld)
5. Have you done any case studies or research? Is there any material that you could send to us to help us with this problem?
6. Do you believe incineration is a good disposal method? We have looked at air pollutant hazard removal systems. Do you think that if we were able to clean up the byproducts/process this would be the best method to use? We have looked into bioremediation as another possible disposal method besides incineration. Have you ever heard of this or looked into a similar process?

Answers:

1. Bought Incinerators from a company in Pennsylvania to dispose of flares that they were selling to their customers.
2. These incinerators were developed for law enforcement agencies to dispose of old munitions.
3. The incinerator was running for a year before the EPA made a filtration rule on the amount of emissions allowed.
4. Datrex contacted the incinerator company in Pennsylvania about a filtration system but they never produced one.
5. The solution was to use a water filter system but this company in Pennsylvania did not follow up with this.
6. Datrex abandoned its incineration program.
7. Had a separate disposal company take flares.
8. People were violating DOT transportation regulations.
9. There is an individual in Las Vegas who is setting up a disposal business but asks to remain anonymous.

10. Datrex could send the flares to back to Sweden where they were manufactured, the manufacturer has a disposal program (incineration) but the costs are prohibited.
11. The manufacturer gave a report of the emissions and found no hazardous chemicals in the emissions or in the ashes after incineration. WPI team asked for report this was sent 2 December 2014 copy below:

    "After incineration of our distress signals, we do not consider the remains to be dangerous but only treat them as a mixture of metallic and non-organic waste. What happens during open burning is that most of the pyrotechnic materials leave as smoke and gasses. If the particles in the smoke is collected or filtered off, you would find a mixture of primarily oxides and chlorides of strontium, magnesium and potassium. If the ashes or the precipitated smoke particles are wetted the pH will be rather high and since bases can be irritating on skin but especially on the eyes and mucous membranes this material should be treated with respect and eye protection, a simple dust mask and gloves is recommended."
12. The Miami Police Dept. incineration program had two incinerators one for rocket flares and one for hand held flares, the two types of flares were separated and properly disposed of, until an incident when the people running the system mixed up the bins causing an explosion and an end to the program.
13. Datrex's incinerator was equipped to handle both types of flares. It had a chute in which the flares were incinerated. It could handle several at a time.
14. Had specific cartons for moving flares (cardboard for handheld and aerial, for the rocket flares they had an internal containment cage that was put into a special carton and labeled appropriately.) All shipping containers met the US DOT and international regulations for shipping.
15. Incinerator was mobile.
16. Surprised by the idea of incineration on the beach though it had to be done somewhere with low population.

Appendix J: Comments from Flare Disposal Poll

Percentage of Boaters Polled (Total Responses: 1,676)	How Do You Dispose of Your Out of Date Flares?
56.4%	I keep my expired flares in storage (at house/on boat)
8.9%	Fire off expired flares on my own.
0.4%	Throw flares overboard.
3.3%	Participate in legal burn days with Coast Guard/fire department/other.
3.1%	Take to local hazardous waste disposal day.
3.6%	Take to hazardous waste disposal site that is regularly open.
13.1%	Donate to a local public service (fire or police department, Coast Guard Auxiliary, etc.)
11.1%	Other

Table 3: Flare Disposal Poll Results (anonymous source, 2014)

Below are the comments from the Flare Disposal Poll. Information connecting organizations to potentially illicit activity was redacted.

- use for teaching USPS [United States Power Squadrons]
- No local, state, fed agency will take them in my area
- Use for Power Squadron training event coordinated with officials. Save others on board for extras. The expiration dates a far to[o] short in the first place. I've never had a flare not fire or work, even after 20+ years.
- It's a racket !!
- Keep them. No place to legally dispose of them locally
- Mine have not expired yet. New boater hoping to find out what to do with them
- combination of keeping , donating for training, or. giving to fire department. depending on our location. only
- one choice would stay Selected
- Fire off to train kids and family
- I would dispose of if I had a good source of doing so.
- one must wait for the dry season and then shoot them off into the woods. this is to keep the fire men busy and in practice

- Store for unknown future disposal - fire or police will not take them
- I keep them for emergencies. (Separate from the un-expired ones.) [But] I've heard they are great for starting a bonfire!
- Soak the flares in a bucket of
- I have not found anywhere to get rid of them, so they are sitting in a pail in my garage
- ???
- store on boat, but need better solution
- put in car
- use to [light] campfire
- I am a member of [redacted]. We have a Safety Event every spring where we can use our about to expire flares.
- Use at [redacted] flare demonstrations
- I keep them as spares. One cannot have too many flares in certain instances
- Flare demonstration with yacht club
- use for emergency in family vehicles
- I'm a newbie and can't wait to see the results of this poll.
- Keep them - never have enough flares if in trouble.
- no one in this area will take them. Leaves me no option but to put in regular trash
- backup spares
- I'm not sure if I should do this or not but I set them off during holidays. I did not know I could donate them so I will start doing that each year.
- July 4th celebration
- Garbage
- Soak them in a bucket of water for 1 week and then dispose by normal means.
- Fire Department had no recommendations. Soaked them in water until mush and buried the remains.
- I read somewhere that if the flares are soaked in water for a week, they are completely inert and can be disposed of anywhere
- Use them to train crewmembers.
- burn handhelds in campfire, or brush burn pile

- use them as emergency highway flare
- [I don't] know how to dispose of them
- I use them from the side of the lake on the 4th of July.
- Nobody seems to want them so they are slowly accumulating in storage.
- use in our training courses.
- keep on Boat for spares
- Been looking for guidance about the right thing to do. Salesperson at West marine didn't know.
- I don t I must have 50 outdated ones I do not know what to do with
- fire off on 4th of July-not on the water.
- not [disposed] yet
- I rotate them to vehicles then purge at 4th of July.
- Soak in water and throw in trash when sopping wet.
- Keep the newest; fire-off oldest (most don't work) in back yard
- take to fire department which disposes of flares
- Duh. If you need flares, you need more than the required number. I keep the expired ones on board.
- fire off flares the 4th of July
- Donate to local Sea Scout troop for training
- local hazardous waste disposal would not accept
- Keep on my boat, just in case!
- Haven't found a way to dispose of them. No HW site or fire department will except them.
- Take them to [the] range and put them on targets for dramatic [effect].
- [They're] laying around waiting to go off. [Don't] know what to do with them
- soak in bucket of water and dispose as [ordinary] trash
- I donate them to the Chapman school for training the students.
- beg the local fire department to [accept] them.
- Expired flare are kept on the boat for an additional cycle, they then go to the car(s) and / or are used to start [campfires].

- Fire off expired flares in driveway at home and place flare in bucket of water when burn is finished. Tried to
- use local police and Coast Guard, but neither have program to dispose of flares.
- KEEP UNTIL VERY OLD THEN BURN ON MY OWN.
- not sure what I'll do when mine expire. what's best? lighting them sounds most fun, but I bet hazardous waste day disposal is correct.
- Include in camping/[hiking] survival kit.
- throw away in garbage
- Don't do anything with old flares
- I use them as road flares for myself, my family, and my friends..
- I still have the expired flares because it is very difficult to get rid of them. I've tried!
- I teach [redacted] for [redacted]. We demo hand held(not aerial) flares for the classes- no [permits] required. We also got West Marine to do a turn in day.
- Keep as spares on boat
- give to local harbormaster for disposal
- use for 4th of July
- dumpster
- I DO A COMBINATION OF THE ABOVE. LOCAL POLICE WON'T ACCEPT THE FLARES BECAUSE THEY DON'T HAVE A SPIKE IN THE BOTTOM FOR MAKING THEM STAND UP ON ROADWAYS
- burn them on july 4
- i did not know what to do with them. Now I will check on donating them! Thanks!
- donate and take [to hazardous] disposal
- keep them
- soak them in a bucket for a few days then break them up while still wet
- Throw them in the trash
- put in trash
- Train family how to use.
- In car or during 4th of July
- slice open & put in bucket of water for months

- light them [up for] holidays.
- Hide in garbage
- water soak and dispose with trash
- put in bucket of water until decayed, unusable, then to the dump
- just because they expire, [dosen't] mean they won't work. keep them on the boat
- # 1 & # 6 properly experience sir!
- Fire on 4th of July
- keep on board in ditch bag
- A local West Marine accepts them and gives them to the local Fire Dept.
- I've never had to dispose of any [yet].
- arsenal on board - no disposal options here
- take to retailer which will dispose the flares appropriately.
- Take to the local fire department
- use to start beach fires
- I keep them in my cars
- take to west marine
- I use the flares to start bonfires
- Carefully open the seal on each, soak in water for a week or more, then dispose. Nobody (CG, fire, police, CG auxiliary) around here will deal with out-of-date flares. Period.
- Have a pile of them, can't find anyone willing to take them
- soak in water until they break down
- Put in truck
- keep on board as additional flares
- dumpster
- several: legal burn days, test expired ones on July 4, keep some expired on boat as backups.
- I light my burn pile
- Even outdated flares still work so I just add new flares to my kit as the dates expire then after about 10 years or so take to hazardous waste
- Thanking about donating them to Safety-At- Sea demonstrations

- use flares in auto trunk if you break down
- NO HAZ MAT DISPOSAL SITE, EMS OR FIRE DEPT WILL ACCEPT XPIRED FLARES. IT IS A MAJOR ISUE AS I AM A USCG AUX COMMERCIAL ANRECREATIONAL VESSEL EXAMINER.
- Keep in auto emer. kit
- burn at home
- 4th of July. Fire off on land with crew for practice and in the midst of other fireworks.
- use as fire starters in my [fire pit]
- Take to county sheriff's office
- Fourth of July with other fireworks well inland away from bodies of water
- Use as backup
- Should be allowed to contact Coast [Guard] with request to use expired flares for training with their approval and your specific location.
- store on the boat/auto emergency kit
- Keep until they show signs of corrosion. Then dispose properly.
- Looking for a way.
- I fire off the flares on New Years or July 4
- Just cause expired doesn't mean bad, carry them onboard as spares.
- Fire off in my back yard
- Get permission from local DNR to fire for crew training
- Fire of expired flares as part of July 1st/4th celebrations.
- keep them on the boat till I get enough then burn them in a coffee can on the 4th of july as there are no other options locally
- Burn handhelds; throw gun types in trash
- Keep one set of [expired] donate remainder to CG Aux.
- Combination of giving to local fire department and keeping some on board the boat
- fire on my own away from navigable water and during periods of public fireworks display, I have ample land to do this safely
- most organizations are unwilling to take [them]
- Use to kill gophers

- Use in cars
- I use them to smoke out moles and gophers in the yard (underground).
- [It's] rolling around under the back seat of my car...
- New Years Eve
- start fire when camping
- Keep'em one of them has to work [eventually]
- Move to my car for road use.
- Move them as emergency flares for my cars
- soak in water/bucket for 6+ months, fell apart
- hide in neighbors trash
- keep in car for road emergencies
- I keep some expired flares on board and dispose of others as instructed by immersing in water
- 4th of july
- keep a couple in each car trunk to use on a roadside emergency.
- I use them to light campfires.
- local Coast Guard safety day
- send to the dump
- I have put them in the trash before
- I light expired hand flares at my inland home. I keep shootables in storage.
- Cut flare in half, soak in a bucket of water over night, then throw in the garbage.
- [separate] powder from [flare, then] discharge. do not have disposal site [available]
- broke in half a soak in water then discard in trash
- trash
- keep mine on boat as USCG/local fire dept will not take them
- Kill Moles
- unable to dispose-no one will take them
- keep in car for emergency on road.....tape to pole use to burn tent [caterpillars] out of fruit trees.
- I keep them, because I don't know other options.

- use for sea scout training
- I keep them on board for use in an emergency to add to the required 3.
- keep on board boat
- Throw them in the trash
- take to West Marine
- Use to start wood fire in an [outdoor] fire pit
- keep all expired flairs in a separate container which is the law according to the USCG

Appendix K: Average Transportation Distance

Starting Location	Starting State	Registered Boaters (p)	Ending Location (Clean Harbors®)	Distance (miles) (s)	s*p
Sector Mobile (08-37160)	AL	265,626	Colfax, LA	390	103,594,140
Sector Los Angeles – Long Beach (11-37260)	CA	820,490	Aragonite, UT	784	631,777,300
Sector San Diego (11-37250)	CA	820,490	Aragonite, UT	815	631,777,300
Sector San Francisco (11-37270)	CA	820,490	Aragonite, UT	711	631,777,300
Sector Long Island (01-37030)	CT	101,887	Colfax, LA	1,553	158,230,511
Sector Jacksonville (07-33231)	FL	870,749	Colfax, LA	808	878,368,053.8
Sector Key West (07-37140)	FL	870,749	Colfax, LA	1,230	878,368,053.8
Sector Miami (07-37110)	FL	870,749	Colfax, LA	1,109	878,368,053.8
Sector St. Petersburg (07-33230)	FL	870,749	Colfax, LA	888	878,368,053.8
MSU Savannah (07-33264)	GA	319,871	Colfax, LA	849	271,570,479
Sector Ohio Valley (08-37200)	KY	174,218	Colfax, LA	756	131,708,808
D8 Gulf of Mexico	LA	307,464	Colfax, LA	269	81,170,496
MSU Morgan City (08-33272)	LA	307,464	Colfax, LA	249	81,170,496
Sector New Orleans (08-37150)	LA	307,464	Colfax, LA	274	81,170,496
Sector Boston (01-37010)	MA	137,668	Colfax, LA	1,692	232,934,256
Sector Southeastern New England (01-37020)	MA	137,668	Colfax, LA	1,722	232,934,256
Sector Baltimore (05-37060)	MD	181,544	Colfax, LA	1,323	240,182,712
Sector Northern New England (01-37000)	ME	107,211	Colfax, LA	1,792	192,122,112
Sector Detroit (09-33270)	MI	795,875	Colfax, LA	1,124	990,466,437.5
Sector Sault Ste. Marie (09-37230)	MI	795,875	Colfax, LA	1,365	990,466,437.5
MSU Duluth (09-33262)	MN	808,744	Colfax, LA	1,267	1,024,678,648
Sector Upper Mississippi River (08-37390)	MO	297,562	Colfax, LA	626	186,273,812
Sector North Carolina (05-33225)	NC	386,884	Colfax, LA	1,089	421,316,676

Sector Buffalo (09-37210)	NY	456,909	Colfax, LA	1,304	627,564,511.5
Sector New York (01-37040)	NY	456,909	Colfax, LA	1,443	627,564,511.5
Sector Columbia River (13-37400)	OR	166,664	Aragonite, UT	932	155,330,848
Sector Delaware Bay (05-37050)	PA	329,578	Colfax, LA	1,418	428,616,189
MSU Pittsburgh (08-33256)	PA	329,578	Colfax, LA	1,183	428,616,189
Sector Charleston (07-37090)	SC	466,589	Colfax, LA	971	453,057,919
Sector Lower Mississippi River (08-37190)	TN	258,167	Colfax, LA	403	104,041,301
Sector Corpus Christi (08-37180) (08-33240)	TX	575,402	Colfax, LA	495	180,868,028.7
Sector Houston – Galveston (08-37170)	TX	575,402	Colfax, LA	261	180,868,028.7
MSU Port Arthur (08-33241)	TX	575,402	Colfax, LA	187	180,868,028.7
Sector Hampton Roads (05-37070)	VA	237,551	Colfax, LA	1,350	320,693,850
Sector Puget Sound (13-37320)	WA	229,403	Aragonite, UT	1,062	243,625,986
Sector Lake Michigan (09-37240)	WI	613,516	Colfax, LA	997	611,675,452
Averages / Totals		**8,909,572**		**963.639**	**8,669,868,526**
SD = ∑(s*p)/b					**973.096 Miles**

Appendix L: R &R Transportation Cost Based on Average Distance

Starting Location	Starting State	Clean Harbors® Contract Rate ($3.50)[1]	R & R Tariff Rates					
			Gas Cost Addition $0.50 per Mile (as of 12/01/2014)	< 1,000 lbs (~$1.71)	1,001 - 3,000 lbs (~$2.12)	3,001 - 5,000 lbs (~$2.36)	5,001 - 7,500 lbs (~$3.03)	Van Rate 7,501 - 42,000 lbs max (~$3.69)
Sector Mobile (08-37160)	AL	1,365.00	195.00	861.90	1,021.80	1,115.40	1,376.70	1,634.1
Sector Los Angeles – Long Beach (11-37260)	CA	2,744.00	392.00	1,732.64	2,054.08	2,242.24	2,767.52	3,284.96
Sector San Diego (11-37250)	CA	2,852.50	407.50	1,801.15	2,135.30	2,330.90	2,876.95	3,414.85
Sector San Francisco (11-37270)	CA	2,488.50	355.50	1,571.31	1,862.82	2,033.46	2,509.83	2,979.09
Sector Long Island (01-37030)	CT	5,435.50	776.50	3,432.13	4,068.86	4,441.58	5,482.09	6,507.07
Sector Jacksonville (07-33231)	FL	2,828.00	404.00	1,785.68	2,116.96	2,310.88	2,852.24	3,385.52
Sector Key West (07-37140)	FL	4,305.00	615.00	2,718.30	3,222.60	3,517.80	4,341.90	5,153.7
Sector Miami (07-37110)	FL	3,881.50	554.50	2,450.89	2,905.58	3,171.74	3,914.77	4,646.71
Sector St. Petersburg (07-33230)	FL	3,108.00	444.00	1,962.48	2,326.56	2,539.68	3,134.64	3,720.72
MSU Savannah (07-33264)	GA	2,971.50	424.50	1,876.29	2,224.38	2,428.14	2,996.97	3,557.31
Sector Ohio Valley (08-37200)	KY	2,646.00	378.00	1,670.76	1,980.72	2,162.16	2,668.68	3,167.64
D8 Gulf of Mexico	LA	941.50	134.50	594.49	704.78	769.34	949.57	1,127.11
MSU Morgan City (08-33272)	LA	871.50	124.50	550.29	652.38	712.14	878.97	1,043.31

[1] Clean Harbors charges an addition 10%-15% to account for fuel and insurance surcharges. This information is neglected in this table because the table only discusses transportation and does not account for disposal costs; however, when looking at the Clean Harbors column of this table this additional fee should be remembered.

Sector New Orleans (08-37150)	LA	959.00	137.00	605.54	717.88	783.64	967.22	1,148.06
Sector Boston (01-37010)	MA	5,922.00	846.00	3,739.32	4,433.04	4,839.12	5,972.76	7,089.48
Sector Southeastern New England (01-37020)	MA	6,027.00	861.00	3,805.62	4,511.64	4,924.92	6,078.66	7,215.18
Sector Baltimore (05-37060)	MD	4,630.50	661.50	2,923.83	3,466.26	3,783.78	4,670.19	5,543.37
Sector Northern New England (01-37000)	ME	6,272.00	896.00	3,960.32	4,695.04	5,125.12	6,325.76	7,508.48
Sector Detroit (09-33270)	MI	3,934.00	562.00	2,484.04	2,944.88	3,214.64	3,967.72	4,709.56
Sector Ste. Marie (09-37230)	MI	4,777.50	682.50	3,016.65	3,576.30	3,903.90	4,818.45	5,719.35
MSU Duluth (09-33262)	MN	4,434.50	633.50	2,800.07	3,319.54	3,623.62	4,472.51	5,308.73
Sector Upper Mississippi River (08-37390)	MO	2,191.00	313.00	1,383.46	1,640.12	1,790.36	2,209.78	2,622.94
Sector North Carolina (05-33225)	NC	3,811.50	544.50	2,406.69	2,853.18	3,114.54	3,844.17	4,562.91
Sector Buffalo (09-37210)	NY	4,564.00	652.00	2,881.84	3,416.48	3,729.44	4,603.12	5,463.76
Sector New York (01-37040)	NY	5,050.50	721.50	3,189.03	3,780.66	4,126.98	5,093.79	6,046.17
Sector Columbia River (13-37400)	OR	3,262.00	466.00	2,059.72	2,441.84	2,665.52	3,289.96	3,905.08
Sector Delaware Bay (05-37050)	PA	4,963.00	709.00	3,133.78	3,715.16	4,055.48	5,005.54	5,941.42
MSU Pittsburgh (08-33256)	PA	4,140.50	591.50	2,614.43	3,099.46	3,383.38	4,175.99	4,956.77
Sector Charleston (07-37090)	SC	3,398.50	485.50	2,145.91	2,544.02	2,777.06	3,427.63	4,068.49

Sector Lower Mississippi River (08-37190)	TN	1,410.50	201.50	890.63	1,055.86	1,152.58	1,422.59	1,688.57
Sector Corpus Christi (08-37180) (08-33240)	TX	1,732.50	247.50	1,093.95	1,296.90	1,415.70	1,747.35	2,074.05
Sector Houston – Galveston (08-37170)	TX	913.50	130.50	576.81	683.82	746.46	921.33	1,093.59
MSU Port Arthur (08-33241)	TX	654.50	93.50	413.27	489.94	534.82	660.11	783.53
Sector Hampton Roads (05-37070)	VA	4,725.00	675.00	2,983.50	3,537.00	3,861.00	4,765.50	5656.5
Sector Puget Sound (13-37320)	WA	3,717.00	531.00	2,347.02	2,782.44	3,037.32	3,748.86	4,449.78
Sector Lake Michigan (09-37240)	WI	3,489.50	498.50	2,203.37	2,612.14	2,851.42	3,519.41	4,177.43
Averages / Totals (USD)		**3,372.74**	**481.82**	**2,129.64**	**2,524.73**	**2,756.01**	**3,401.65**	**4,037.65**
Using SD (USD)		**3,405.84**	**486.55**	**2,150.54**	**2,549.51**	**2,783.05**	**3,435.03**	**4,077.27**

Appendix M: Approximate PVDS Weight Calculations

Approximate PVDS Weight Calculations					
Product Name	Case Weight	Products per Case	Flares per Product	Flare Weight Lbs	Average Weight
20 min 6pack	14.6	4	6	0.608333333	
30 min 6pack	18.36	4	6	0.765	
day/night flare/smoke	5.3	10	1	0.53	
locator marine hand held red flare signal pack	4.8	4	4	0.3	
hand held red flare signal bulk	22.5	72	1	0.3125	0.503167
red hand held flare Solas	3	6	1	0.5	
red hand held flare Solas Bulk	7	24	1	0.291666667	
White hand held signal	3	6	1	0.5	
White hand held signal bulk	7	24	1	0.291666667	0.395833
Pocket Rocket 4 aerial signal kit	2.25	6	1	0.375	
pocket rocket replacement signals	1.5	6	1	0.25	
skyblazer 2 aerial signal kit	0.666	4	1	0.1665	
skyblazer 2 aerial signals bulk	4.5	36	1	0.125	
12 gauge high perf. Aerial signal pack	1.5	6	4	0.0625	0.1958
illuminating parachute rocket white	2	4	1	0.5	
red parachute signal rocket solas	2	4	1	0.5	0.5
orion smoke hand held	1.5	6	1	0.25	0.25
orange solas floating smoke	1.8	4	1	0.45	0.45
Overall Average Weight----------->>>>>>>					0.376565

KEY	
Hand held	Hand held Solas
Aerial	Aerial Solas
Smoke	Smoke Solas

Note: All data from: http://www.orionsignals.com/products It was not possible to determine whether listed weights considered packaging, as a conservative esimate for flare weight we will use .5 lbs for all calculations in this report