Iceberg Differentiation

A Project Report
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Degree of Bachelor of Science
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Projects in Electrical and Computer Engineering

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Abstract

The United States Coast Guard's International Ice Patrol (IIP) flies hundreds of hours annually over the Grand Banks of Newfoundland performing iceberg reconnaissance. They report their findings on the locations of icebergs to mariners, who cannot necessarily see the icebergs due to deep fog, to ensure safe navigation. The IIP requires an iceberg-locating device so that they will not have to dive below normal operating altitude for visual confirmation every time a target's designation is questionable.

The IIP has sponsored a cadet project at the USCG Academy to research and recommend a radar direction finding device to differentiate between icebergs and vessels. This will save them time, resources, and money. Furthermore, the IIP's mission effectiveness will improve, since they will have the tools needed to correctly plot the location of icebergs and provide safer transit in the area.

Of the three potential systems that would meet the IIP's requirement specifications, the ALR-95(V) was selected for further testing. The project team tested the ALR-95(V) and found that the system meets the needs of the IIP and can also be used for other Coast Guard missions. The system should be integrated into the C-130J through the Coast Guard's asset upgrade program named Deepwater.

Introduction

An iceberg can lead to a fatal collision with a vessel, given the right set of circumstances, as seen in the tragedy of the “unsinkable” RMS Titanic in 1912. Two of the Coast Guard’s five primary missions are meant to prevent incidents such as these; maritime safety and maritime mobility. Iceberg Differentiation (ID) is the act of determining whether a certain contact is a vessel or an iceberg. The IIP has sponsored a cadet project at the United States Coast Guard Academy to research and recommend a radar direction finding device to potentially be installed on an airframe and be used to differentiate between icebergs and vessels. This project will explore the feasibility of implementing an ID system for the International Ice Patrol (IIP). Their mission is to “monitor iceberg danger near the Grand Banks of Newfoundland and provide the limits of all known ice to the maritime community.” Such a system would save the IIP and the USCG money in time and resources and would provide all vessels in the area with a safer transit route, avoiding all known icebergs.

With the information acquired from this type of system, the IIP can provide the locations of all icebergs to mariners in the Grand Banks area, providing a safer transit. The practicality and cost of the system must be taken into consideration, as well as the fact that the IIP does not need to know that a specific vessel is on a specific bearing, but rather that there is a vessel and not an iceberg on the surface. If a contact is detected on an active radar (a radar that sends and receives a signal), the IIP might not be able to tell, even with the many tools they have available, if the target is an iceberg or a vessel. Consequently, the IIP often has to deviate from the search pattern to dive below the thick clouds to visually detect the target. If a radar direction finder were installed on the airframe, the IIP could read the bearing to the target from the signal receiver and determine whether or not the active target correlates with the signal. If there is correlation, then there is no need for a visual confirmation and the use of extra time and fuel to descend below the clouds. If there is no signal detected for an active radar target, the IIP cannot assume that the target is an iceberg. Fishing vessels may have their radars turned off, causing them to appear as icebergs, and therefore a visual identification may still be required. An assumption is made in this project that that all ships in the area continuously operate their radar. This is reasonable because a vessel’s radar will be energized and active unless its power is completely cut off or if

the captain manually turns off the ship's radar. Neither situation is safe. Another assumption is that the small fishing vessels will have their AIS turned off and will not respond to hails on their VHF radio. For further explanation of the need for such a system, reference this project's business case, located in Appendix A.

The project team analyzed various systems which would meet the needs of the IIP and found that several were already being researched for Coast Guard airframes. The Canadian Coast Guard uses a wingtip receiver system installed on the Convair 580 airframe which operates through interferometry, as explained further in Appendix E. The ALR-66 is being used by the US Navy and is currently being phased out of service. The initial idea was to try and get the systems from the Navy for Coast Guard use. However, the system is being stripped from the airframes. The system is being replaced, but the antennas are remaining on the aircraft to be used with a new system. Transfer of the system to USCG assets is therefore impossible.

The ALR-95(V), a radar system developed by ITT, received the majority of the team's focus and is being placed on the HC-144 CASA, the new airframe chosen by Deepwater to replace the missions of the current HU-25 Falcon. This system uses passive radar for the purpose of direction finding and Signal Emitter Identification (SEI). SEI uses radar fingerprinting to match a vessel's radar signature, or signal characteristics, against a database of signatures.

The ALR-95(V) was chosen for further testing. A test plan was drawn up, and implemented. The US Navy at Naval Air Station Brunswick (NASB) and the US Coast Guard at Sector Northern New England (SNNE) as well as the *Jefferson Island* 110' Cutter worked together to test the ALR-95(V). The results of the test were positive and support the conclusion that the Coast Guard would benefit greatly from having the ALR-95(V) system installed on the new HC-130J airframes. This paper, will explain where the need for this project came from, the goals of the project, the planned solution, and the results from that solution.

Background

When the *Titanic* sank due to an iceberg collision, the horrific effects were felt all across the world. The Safety of Life at Sea (SOLAS) convention decreed international cooperation to patrol the area off of the Grand Banks tracking icebergs [1]. As of 2005, there are 17 nations who

share the cost of iceberg reconnaissance: Belgium, Canada, Denmark, Finland, France, Germany, Great Britain, Greece, Italy, Japan, Netherlands, Norway, Panama, Poland, Spain, Sweden, and the United States [1]. The Coast Guard provides the ice patrol service in conjunction with other countries to ensure safe navigation.

The U.S. Coast Guard is tasked with the United States' iceberg patrols. The IIP performs iceberg reconnaissance in Coast Guard HC-130 aircraft, flying hundreds of hours annually over the Grand Banks of Newfoundland [2]. The Labrador Current runs southeast, carrying icebergs along the coast of Canada into the Grand Banks and the great circle shipping lanes [3].The IIP uses the data acquired from their patrols to place the discovered icebergs on charts [3]. From this information the IIP can draw a virtual line in the ocean to alert vessel traffic as to where these icebergs are located. This line is called the Limit of All Known Ice (LAKI) [1]. If the LAKI is drawn too far south, vessels must travel longer routes which are more costly.

Weather conditions on the Grand Banks, including thick fog (70% to 80% of the time) and low cloud ceilings of 200 ft, seldom afford opportunities for visual reconnaissance [1]. The normal operating altitude for the IIP is between 5500 ft and 8000 ft. Due to the foul weather conditions the planes often have to dive below the normal operating altitude to 400 ft in order to attempt visual confirmation. According to IIP data, "the tallest known iceberg in the North Atlantic was 550 ft high", which makes the dives dangerous [4]. These dives, which range from half an hour to an hour, are often a waste of resources, as a deviation does not necessarily mean positive or negative iceberg identification. The aircraft could considerably dive down and still not have a visual on a surface contact. The IIP must assume the worst, so the idea of an iceberg cannot be eliminated.

The normal operating cost of an Ice Patrol flight is $14,237 per hour as per the Coast Guard Standard Rates directive [5]. A normal patrol lasts seven hours and covers more than 1600 miles [4]. A review of flight paths from 2007 shows that in a six-month period, there were about 102 deviations from the search pattern, totaling approximately $238,000 per month (based on the aforementioned cost of $14,237 per hour) [3]. The IIP has an annual budget of $5.9 million [4]. Therefore, these dives use approximately half of the IIP's budget.

Despite having ice observers at the windows of the airframe and as a result of the low visibility, the IIP relies heavily on active radar systems. Radar is used "for transmitting electromagnetic signals and receiving echoes from objects of interest (targets) within its volume of coverage" [6]. The radar systems currently used by the IIP are both active and include the Raytheon APS-137 Forward Looking Airborne Radar (FLAR) and the Motorola APS-135 Side Looking Airborne Radar (SLAR). The FLAR uses active radar to track objects and determine their course and speed. The types of objects that the system tracks range from vessels, to icebergs, to debris in the water.

The SLAR is an active radar that tracks objects and uses real time imagery to determine what the object is. The SLAR is very effective for icebergs larger than fifteen meters, but is not sufficient for smaller icebergs due to the poor image resolution. The best way to determine whether an object is a vessel or an iceberg, using SLAR, is to look for a wake behind the object. If the object has a wake, then it must be a vessel.

Another sensor available to the IIP for the convergence of evidence is the Automatic Identification System (AIS), which can be used to acquire surface vessels' names, locations, and other specific data. AIS is the best way to determine whether an object is a vessel or an iceberg. The downside of AIS is that although larger vessels are required to use it, smaller fishing vessels are not [4]. The SLAR, FLAR, and AIS, when used together, can typically identify and classify targets as icebergs or ships [2]. Positive identification, however, is not always possible.

Radar is not accurate enough to detect icebergs as a standalone system, as shown in the most recent tests available which were conducted in 1945, 1946, and again in 1959 [1]. These tests found that glacial ice in the Grand Banks "reflects radar waves 60 times less than a ship of equivalent cross-sectional area" with a reflection coefficient of 0.33 [1].The tests also found that at greater than four miles, medium size floes and growlers, icebergs smaller than 3ft by 16 ft, can not be detected [1]. Another pertinent note from the tests was that waves over four feet can cause a type of radar interference called sea clutter, which makes it difficult to discover a growler in the area [1]. Sea clutter is caused by the reflectivity of the sea and the coefficient "depends on the sea state and wind conditions, as well as the relative angle between the look direction and the

wind direction. The reflectivity is a strong function of wavelength, depression angle, and polarization of the [Electromagnetic (EM)] wave" [7].

Unfortunately, a large number of the ships on the Grand Banks during the iceberg season are small fishing vessels that are not required by their government to carry AIS. According to the IIP, this is because AIS systems are too expensive to expect small fishing vessels to own and operate. These small vessels can be hidden in the sea clutter just like growlers. If detected, making a differentiation between the vessel and an iceberg can be very challenging. When hailed on the VHF radio, small fishing vessels often will not answer, as they do not want their fishing location to be broadcasted.

The IIP specifically requested a radar signal direction finder be used to solve their surface contact identification problem. A direction finder only receives a signal, while the active radars already installed on the airframe send and receive signals. A direction finder can be created and installed on the airframe by designing an antenna specifically for the radar frequency bands. In the case of marine navigation, S band and X band radar signals are sent out by a vessel's active radar system [8]. This vessel then receives the signal's echo from a nearby target; nearby meaning within range of the radar. The signal the vessel is sending out in search of targets can be detected by a direction finder, provided it is designed to find signals at the right frequencies [6].

Electronics Intelligence (ELINT) is valuable information not only for national defense, but also for humanitarian situations like search and rescue, where in both cases vessel identification is desired. Signals emitted from vessels can be collected, used for vessel identification, and can even be processed to find vessel locations through a process called interferometry (Please see Appendix E for a technical description of interferometry). One common signal sent out by vessels at sea is a radar signal, which is used by the vessel for navigation and weather detection. These radar pulses are mostly S band (2-4 GHz) and X band (8-12GHz) radar signals that can be detected by surveillance aircraft [7].

In conjunction with the Deepwater project, the United States Coast Guard has chosen ITT's ALR-95(V) maritime patrol system to be incorporated into the CASA and potentially the C-130J airframes. The Coast Guard has a requirement for the new C-130J airframes to have Electronic Support Measures (ESM) capability. The ITT Corporation has a contract with the

Coast Guard to supply their radar detection system the ALR-95(V) for the CASA airframe. However there is no requirement or plan to support the older H-model, currently used by the IIP, with such equipment. Although the IIP needs the ELINT equipment, the old H-model will eventually be replaced by the J-model, so updating old airframes may not be cost beneficial.

Objective

The IIP requested a system that met four basic requirements. These requirements can be seen in the Functional Requirements Document (Appendix C) in detail, and are listed below:

1. System will have a visual interface with a geo-position for surface contacts which is usable by a trained operator.
2. Detect X-band and S-band radar signals.
3. Operable at altitudes of 5500 to 8000 ft.
4. System must be attainable and testable.

The first requirement is needed because the IIP must be able to collect data in a timely manor as they fly over hundreds of icebergs in a day. The second requirement is needed because the IIP specifically wanted a radar detection finding system and through research the team found that S and X band are the bands at which vessel radar operates. The third requirement is needed because the system must be operable at the altitudes of IIP operation. Lastly, the system must be obtainable for testing so that a conclusion on a recommendation can be given to the IIP. The deliverable to the IIP is this paper containing a written recommendation.

This project was completed over the course of two semesters. The fall semester was devoted to research, while the spring semester focused on testing. Research into the various systems on the market, as well as choosing a system to focus on, was conducted in the fall. In the spring semester a test plan was written, tested, and the results analyzed. A detailed planning of events is included in Appendix B, the Project Management plan, which discusses the steps and timing taken for this project in detail.

There were a few resource constraints associated with this project. First, the fourth requirement meant that we needed to find a system that actually had the potential to be used by the Coast Guard, which limited the system we could choose to test. Secondly, the system we choose had to solve the problem of distinguishing a vessel and an iceberg using radar differentiation. This meant that other options, such as thermal imaging could not be explored. A point to consider, but is not a requirement is that the current IIP mission crew of six is made up of a tactical commander, two ice observers, two radar operators, and one radar ice observer to correlate contacts between the ice observers and the radar operators. Expected crew sizes for IIP missions will remain about the same as they are now.

System Design

The design solution was the plan that the researchers followed to ensure that the IIP's needs were incorporated into the future plans of the Coast Guard. Four main steps were created, as seen in the attached flow chart located in the Functional Requirements Document in Appendix D. The four steps were to find existing technology, test the technology, revise the technology, and to research the cost of the system. In the Fall of 2007 the team conducted the first step of the process by finding existing technology. The Spring Semester of 2008 was used to test the chosen technology. Cost was researched as a part of the system design considerations throughout the project. The technology revision section of the project was not feasible because the systems are premade by various companies. Three systems were found which held promise, a Canadian system, the ALR-66, and the ALR-95(V). The ALR-95(V) was ultimately chosen for testing as the design solution.

The first system to be researched was a system designed by the Canadian Government's Defense Research Establishment Ottawa (DREO). The system was an interferometric system which used the basic communication theory of in-phase and quadrature-phase demodulation (IQ demodulation) as well as antenna design in order to find the location of the signal emitting vessel. The technical aspects of this system are described in Appendix E. This system appears as if it could meet the requirements of the IIP in terms of frequency band collection; however the system did not meet requirement number four of being obtainable for testing. The Canadian government has classified the system as Top Secret and is undergoing further testing at the

Canadian Research and Development Center. This system was not chosen for testing due to its classification.

The second system found in research was the ALR-66 and the third is the ALR-95(V). The US Navy is currently phasing out the ALR-66. At first this appeared like a good opportunity to obtain a system for Coast Guard use, however, the Navy is keeping certain aspects of the system, such as the spinning antenna. Once again, the fourth requirement of having an obtainable system was not met and the research team needed to explore another system option. The Coast Guard will not be able to obtain the old systems, so the ALR-95 was chosen for research. The ALR-95(V) will have a support system and a training program, under the CASA program, which the C-130J could utilize, should the system become a reality as discussed in our functional requirements document found in Appendix C.

Since the Navy was upgrading the ALR-66 to the ALR-95(V), the ALR-95(V) appeared like the right system to explore. The team looked at the requirements set fourth by the IIP and found that three of the four requirements were met and the fourth requirement could be tested. The first requirement of having a user-friendly interface as well as the second requirement of covering the S and X band frequencies both appeared to be met by talking to Naval ALR-95(V) operators as well as by looking at system manuals. For specifics on the interface and the ALR-95(V) system design, please refer to the Design Specifications contained in Appendix H. Furthermore, a list of the system's sensitivity specifications can be found in Appendix J. The third requirement of specific operating altitudes could be tested provided the fourth requirement was met. The United States Navy at Naval Air Station Brunswick and Sector Northern New England agreed to provide the resources necessary to test the ALR-95(V), meeting requirement four.

After the first phase of research was completed, the second phase of the design was completed; this involved creating a test for the ALR-95 (V). The researchers wrote a test plan to be conducted in a joint Navy and Coast Guard operation. Sector Northern New England coordinated with CGC Jefferson Island to provide a vessel surface contact for the evolution. Naval Air Station Brunswick supplied a P-3 Orion equipped with an ALR-95(V) and crew. The aircraft flew over the vessel and recorded the position of the vessel according to readings from

the ALR-95(V) and the active radar (APS-137). CGC Jefferson Island was given a handheld GPS receiver to record their actual location. When the data was correlated in time, the researcher hoped to see that the aircraft systems aligned in time with the cutter locations. This test plan is included as Appendix F and explains how the requirements were tested as well as contact information for the people who conducted the operation.

The third and final phase of the project was to analyze the test results and determine whether or not the system is suitable for the IIP and for the Coast Guard as a whole.

Results

The numerical results of the test plan have been classified as SECRET. This SECRET Appendix can be obtained through the Electrical Engineering Department at the United States Coast Guard Academy on a need-to-know-basis.

The test results in general showed that the ALR-95(V) would be operable at 5500-8000 ft. The test was able to successfully complete SEI as well as find reliable bearings to the vessel. The track-line taken by USCGC Jefferson Island can be seen in Figure 1 and the GPS data (latitude, longitude, time…) collected can be reviewed in Appendix G. Aircraft measurements, using the active radar and the ALR-95(V), of the vessel's location have been classified as SECRET by the US Navy.

Figure 1: USCGC Jefferson Island Track line 02APR08

Through e-mails with various Coast Guard personnel, we identified the costs associated with installing and maintaining the ALR-95(V) system on the CG-130J airframe. Appendix I consists of a series of e-mails exchanged around various Coast Guard Members to track down specific expenses. The cost of the system is not set in stone, but is expected to be $17 million dollars to place the ALR-95(V) into the C-130J Mission System on all six aircraft (information provided by Rick Seitz, C-130 Projects Manager, CG-931, Aviation Acquisition). Training and maintenance programs will be up and running in the Coast Guard for the CASA airframe, so funding will be need to increase for these assets. Presently, the associated costs are not known for the CASA, as contracts are still in the process of being signed. Training is a concern because the Navy operators attend a six month school on the system, and then the ALR-95(V) is the only system they operate when they are flying in the P-3 Orion. The ALR-95(V) requires specialized training which needs funding.

In an ideal situation, the ALR-95(V) would prevent all IIP diverts. If that were the case, all of the 102 diverts for the 2007 season would not have occurred and the Coast Guard would have saved $1.45 million dollars (based on the aforementioned cost of $14,237 per hour of

operation and diversions taking an hour). Sometimes there will be a contact on the surface that is not emitting a signal. In this case, the IIP will still have to dive below the clouds to see the contact since the contact could be a vessel with its radar deactivated. Therefore, the estimate of actual saved dollars is divided in half. A realistic estimate of the amount of money saved by installing an ALR-95(V) in the C-130J airframe just from IIP mission use in a six month period is $726,000. Although the system may cost $17 million dollars to place on all six of the C-130J airframes, other areas of the Coast Guard may be able to save money by using this ALR-95(V) system for their specific mission. Further research should be conducted by other Coast Guard branches to see how they would use the ALR-95(V) system and the expected savings. The benefits of this system, in regards to the ELINT technology are vital to the future of the Coast Guard and homeland security. The benefits provided by the system capabilities of the ALR-95(V) outweigh the monetary cost.

Conclusions

A form of direction finding technology would be beneficial to many aspects of Coast Guard missions. Not only will a radar direction finder be able to aid the IIP missions, but it will also aid the service in search and rescue, fisheries, and even law enforcement. The device could be used by airframes and cutters to obtain bearings to vessels in distress, as well as illegal fishing vessels which will not answer when hailed on VHF nor carry AIS. Boarding team members might be able to match a signal from a vessel to the intelligence signals library and know pertinent information, such as nationality, previous illegal activities on that vessel, and the name of the vessel before embarking on a boarding.

This semester was spent researching various systems that could be potential solutions for the IIP, as well as acquainting ourselves with the missions of the IIP. The research team found three systems that could theoretically meet the needs of the IIP: one top secret project at the Canadian Research and Development Center, the ALR-66, and the ALR-95. The team has concluded that the ALR-95(V) meets the needs of the IIP and would be beneficial to the Coast Guard as a whole. The ALR-95(V) would be obtainable and maintainable by the Coast Guard, as the system is already incorporated into the Deepwater program.

The system would mainly be used to find the direction of a vessel's radar signal. However, if combined with the other technological equipment in the cockpit, the system could become an automated unit used in all Coast Guard missions.

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Appendices

Appendix A: Business Case

Appendix B: Project Management Plan

Appendix C: Functional Requirements Document

Appendix D: Support Plan

Appendix E: Specific Technical Background

Appendix F: Test Plan

Appendix G: Cutter Handheld GPS Data Table

Appendix H: Design Specifications

APPENDIX A: Business Case

Iceberg Differentiation
BUSINESS CASE
September 21st, 2007

By: Abigail Lafond &Bryan Weber

Needs:

The International Ice Patrol (IIP) flies hundreds of hours annually over the Grand Banks of Newfoundland performing iceberg reconnaissance in Coast Guard HC-130 aircraft. Weather conditions on the Grand Banks, including thick fog (70% to 80% of the time) and low cloud ceilings, seldom afford opportunities for visual reconnaissance. Due to the foul weather conditions the planes often have to dive below the normal operating altitude to 400 ft. These dives, taking between half an hour to an hour, are often a waste of resources, as a deviation does not necessarily mean positive or negative iceberg identification. The normal operating cost of an Ice patrol is $14,000 per hour as per the Commandant's Directives. There were about 102 deviations in a 2007 six month period from the search pattern, totaling at least $2856000 per year.

As a result of the low visibility, IIP relies heavily on radar systems, including the APS-137 (made by Raytheon) Forward Looking Airborne Radar (FLAR) and APS-135 (made by Motorola) Side Looking Airborne Radar (SLAR), as well as other sensors, including Automatic Identification System (AIS), to detect surface targets, and classify them as icebergs or ships. Unfortunately, a large number of the ships on the Grand Banks during the iceberg season are small fishing vessels that are not required to carry AIS, making such differentiation very challenging. Furthermore, when hailed on VHF, small fishing vessels often will not answer, as they do nnot want their fishing location to be broadcasted.

The IIP uses the data acquired from these patrols to place the icebergs on charts. From this information the IIP can draw a drift line in the ocean to alert vessel traffic as to where these icebergs are located. If the line is drawn too far south, vessels must travel longer routes which are more costly. The ice patrol Coast Guard mission provides this service in conjunction with the surrounding countries to ensure safe navigation.

Therefore, the IIP has requested a new cost beneficial system which will not be affected by adverse weather conditions, which will allow for the distinction between fishing vessels and icebergs, and will accurately provide the positions of these objects using radar detection.

Objectives:

Since most small fishing vessels have radar. A type of radar diction device is thought to be the best way to tell the difference between a fishing vessel and an iceberg. However, other signal detection should not be discredited. The objectives of this project for the next seven months are split into four parts. First, the researchers must fully acquaint themselves with the literature and state of research associated with signal detection technology. Secondly, the availability and practicality of implementing a scaled back implementation of the technology must be explored. Thirdly, the technology must be evaluated to determine if an HC-130 patrolling at 5500-8000 ft would be able to carry such equipment. Lastly, a cost analysis would need to be conducted to approximate the expense of outfitting a HC-130 with that technology.

Purpose:

A form of radar detection technology would be beneficial to many aspects of Coast Guard missions. Not only will a radar detector be able to aid the IIP missions, but also aid the service in search and rescue as well as fisheries. The IIP is expected to save at least 2.8 million dollars per year should the airframe gain a reliable radar detection device. This estimate only counts the expected savings the IIP would see, not taking into consideration the impact such technology would have on other Coast Guard missions. A radar detection device could be used by airframes and cutters to obtain bearings to vessels in distress, as well as illegal fishing vessels which will not answer when hailed on VHF.

APPENDIX B: Project Management Plan

Iceberg Differentiation

PROJECT MANAGEMENT PLAN

October 9th, 2007

By: Abigail Lafond &Bryan Weber

1. **Introduction:** This plan will serve as a guideline to which the success of our project will be measured throughout the design, implementation, and testing phases.

1.1. **Project Background:** The International Ice Patrol (IIP) flies hundreds of hours annually over the Grand Banks of Newfoundland performing iceberg reconnaissance in Coast Guard HC-130 aircraft. Weather conditions on the Grand Banks, including thick fog (70% to 80% of the time) and low cloud ceilings, seldom afford opportunities for visual reconnaissance. Due to the foul weather conditions the planes often have to dive below the normal operating altitude to 400 ft. These dives, taking between half an hour to an hour, are often a waste of resources, as a deviation does not necessarily mean positive or negative iceberg identification. The normal operating cost of an Ice patrol is $14,000 per hour as per the Commandant's Directives. There were about 102 deviations in a 2007 six month period from the search pattern, totaling at least $2,856,000 per year.

As a result of the low visibility, IIP relies heavily on radar systems, including the APS-137 (made by Raytheon) Forward Looking Airborne Radar (FLAR) and APS-135 (made by Motorola) Side Looking Airborne Radar (SLAR), as well as other sensors, including Automatic Identification System (AIS), to detect surface targets, and classify them as icebergs or ships. Unfortunately, a large number of the ships on the Grand Banks during the iceberg season are small fishing vessels that are not required to carry AIS, making such differentiation very challenging. Furthermore, when hailed on VHF, small fishing vessels often will not answer, as they do not want their fishing location to be broadcasted.

The IIP uses the data acquired from these patrols to place the icebergs on charts. From this information the IIP can draw a drift line in the ocean to alert vessel traffic as to where these icebergs are located. If the line is drawn too far south, vessels must travel longer routes which are more costly. The ice patrol Coast Guard mission provides this service in conjunction with the surrounding countries to ensure safe navigation.

1.2. **Product Description:** The IIP has requested the study and design of a system which will not be affected by adverse weather conditions, will allow for the distinction between fishing vessels and icebergs, will accurately provide the positions of these objects, and will remain within the budget of the IIP.

According to electrical engineering expert Sybil P. Parker, "passive radar can locate a source of radiation accurately in direction and discriminate between nearby targets" (Parker 661). Although the specific range to a target can not be determined through passive radar, the project should explore possibilities in this area. The kinds of signals detected should not be limited to the microwaves emitted from a shipboard radar, and should include the possibility of GPS signals as well.

This is a first year project at the United States Coast Guard Academy, and therefore there is no previous student information to recite. However, the United States Navy has a Specific Emitter Identification (SEI) network in place that helps naval ships, aircraft and land-based units identify ships based on the signals they emit. This project would not need the entire network capabilities of the USN, but the signal detection aspect could be utilized once classified information is obtained.

1.3. **References:** N/A

2. **Roles and Responsibilities:**

Project Sponsor: *International Ice Patrol*

Project Advisor: LT *Rhett Rothberg*

Team Members: *1/c Bryan Weber and 1/c Abigail Lafond*

2.1. The researchers must fully acquaint themselves with the literature and state of research associated with signal detection technology.

2.2. The availability and practicality of implementing a scaled back implementation of the technology must be explored.

2.3. The technology must be evaluated to determine if an HC-130 patrolling at 5500-8000 feet would be able to carry such equipment.

2.4. A cost analysis will need to be conducted to approximate the expense of outfitting a HC-130 with that technology.

3. **Project Description, Schedule, and Resources**

3.1. **Project Work Breakdown Structure (WSB):** See attached

3.2. **Resource Estimates:** N/A

3.3. **Schedule:** See attached

3.4. **Communication Plan:** N/A

Project Management Plan Table

Iceberg Differentiation

	ACTIVITY	***PREDECESSOR***	***CLASS DUE DATE***	***OUR DUE DATE***	***TIME REQUIREMENT***	***RESOURCES***
A	Interim Design Paper	—	25JAN	25JAN	2 weeks	• Bryan tasking Abbey • Meet with CDR Godfrey
B	Lunch Presentation	C	04FEB	04FEB	1 week	• Abbey tasking Bryan
C	Revised PMP	—	04FEB	29FEB	2 weeks	Abbey
D	Draft Poster	—	08FEB		1 week	Bryan
E	Final Poster	D	15FEB	15FEB	1 week	• Bryan tasking Abbey
F	Draft Test Plan	—	21MAR	21FEB	3 weeks	• Bryan will divide test plan outline into sections and task Abbey
G	Draft Design Specification	—	04APR	04APR	2 weeks	• Bryan tasking Abbey
H	Draft Project Paper	A, C, U, Z,AA	18APR	14APR	3 weeks	• Abbey tasking Bryan
I	Project Paper	Y	25APR	25APR	5 days	• Abbey tasking Bryan
J	Project Presentation	M	30APR		1 week	• Bryan divides by slide topics and assigns Abbey which slides to create/talk about
K	Notebooks/Binder	U	05MAY		1 week	• Bryan tasking Abbey
L	Set Date for Exercise	—	—	14FEB	1 month	LT Rothberg and Abbey
M	Test ALR-95	N, O, U	—	10APR	1 month (Window from 24MAR-10APR)	LT Rothberg, Bryan and Abbey go up in the flight in Maine
N	Set CG Assets/Paperwork	L	—	14FEB	1 month	• LT Rothberg tasks Bryan and Abbey

O	Set Navy Assets/Paperwork	L	—	14FEB	1 month	• Abbey is POC
P	Fly with IIP on a Mission	—	—	—	—	LT Rothberg
Q	Receive Feedback from IIP on Test Plan (meet 1230 28FEB?)	W	—	28FEB	4 days	• Bryan tasking Abbey
R	Revised Test Plan and Sent to CG and Navy	Q	—	02MAR	4 days	• Bryan tasking Abbey
S	Get Revisions of Test Plan from CG	R	—	17MAR	2 weeks	• Bryan tasking Abbey
T	Get Revisions of Test Plan from Navy	R	—	17MAR	2 weeks	• Abbey tasking Bryan
U	Final Test Plan	S, T	—	20MAR	4 days	• Bryan tasking Abbey
V	LT Rothberg Provides Test Plan Feedback	F	—	24FEB	3 days	LT Rothberg
W	Revise and E-mail Test Plan to IIP	V	—	26FEB	2 days	• Bryan tasking Abbey
X	Writing Center with Draft Project Paper	H	—	15APR	4 days	• Abbey tasking Bryan
Y	Receive Feedback from LT Rothberg on Project Paper	X	—	20APR	3 days	LT Rothberg
Z	Analyze Test Results	M	—	11APR	7 days	• Abbey tasking Bryan
AA	Cost Analysis	—	—	06MAR	30 days	• Abbey tasking Bryan

APPENDIX C: Functional Requirements Document

Iceberg Differentiation

FUNCTIONAL REQUIREMENTS DOCUMENT

October 19th, 2007

Modified 01May08

By: Abigail Lafond &Bryan Weber

1. INTRODUCTION

1.1 Project Description

The International Ice Patrol (IIP) flies hundreds of hours annually over the Grand Banks of Newfoundland performing iceberg reconnaissance in Coast Guard HC-130 aircraft. Weather conditions on the Grand Banks, including thick fog (70% to 80% of the time) and low cloud ceilings, seldom afford opportunities for visual reconnaissance. Due to the foul weather conditions the planes often have to dive below the normal operating altitude to 400 ft. These dives, taking between half an hour to an hour, are often a waste of resources, as a deviation does not necessarily mean positive or negative iceberg identification. The normal operating cost of an Ice patrol is $14,000 per hour as per the Commandant's Directives. There were about 102 deviations in a 2007 six month period from the search pattern, totaling at least $2,856,000 per year.

As a result of the low visibility, IIP relies heavily on radar systems, including the APS-137 (made by Raytheon) Forward Looking Airborne Radar (FLAR) and APS-135 (made by Motorola) Side Looking Airborne Radar (SLAR), as well as other sensors, including Automatic Identification System (AIS), to detect surface targets, and classify them as icebergs or ships. Unfortunately, a large number of the ships on the Grand Banks during the iceberg season are small fishing vessels that are not required to carry AIS, making such differentiation very challenging. Furthermore, when hailed on VHF, small fishing vessels often will not answer, as they do not want their fishing location to be broadcasted.

The IIP uses the data acquired from these patrols to place the icebergs on charts. From this information the IIP can draw a drift line in the ocean to alert vessel traffic as to where these icebergs are located. If the line is drawn too far south, vessels must travel longer routes which are more costly. The ice patrol Coast Guard mission provides this service in conjunction with the surrounding countries to ensure safe navigation.

Therefore, the IIP has requested a new cost beneficial system which will not be affected by adverse weather conditions, which will allow for the distinction between fishing vessels and icebergs, and will accurately provide the positions of these objects.

1.1.1 Background

Every object emits some kind of electromagnetic radiation which can be detected by passive radars. A passive radar detects signals such as microwaves emitted by ships' radars. When a ship's radar is energized, the signals sent out to detect fish, other ships, weather or land, can be intercepted by anything with a radar receiver. A direction finder is needed to accurately locate a source of radiation. Although the specific range to a target is not expected to be determined, the project should explore possibilities in this area.

1.1.2 Purpose

Since most small fishing vessels have radar. A type of radar diction device is thought to be the best way to tell the difference between a fishing vessel and an iceberg. However, other signal detection should not be discredited. The objectives of this project for the next seven months are split into four parts. First, the researchers must fully acquaint themselves with the literature and state of research associated with signal detection technology. Secondly, the availability and practicality of implementing a scaled back implementation of the technology must be explored. Thirdly, the technology must be evaluated to determine if an HC-130 patrolling at 5500-8000 ft would be able to carry such equipment. Lastly, a cost analysis would need to be conducted to approximate the expense of outfitting a HC-130 with that technology.

A form of radar detection technology would be beneficial to many aspects of Coast Guard missions. Not only will a radar detector be able to aid the IIP missions, but also aid the service in search and rescue as well as fisheries. The IIP could save up 2.8 million dollars per year should the airframe gain a reliable radar detection device. This estimate only counts the expected savings the IIP would see, not taking into consideration the impact such technology would have on other Coast Guard missions. A radar detection device could be used by airframes and cutters to obtain bearings to vessels in distress, as well as illegal fishing vessels which will not answer when hailed on VHF.

1.2 Assumptions and Constraints

We are assuming that the Coast Guard will have enough money and want to implement a radar direction finder. Also, once fitting on board the HC-130, the direction finder will not interfere with other equipment. In addition, we assume that the majority of the vessels in the grand banks off of Newfoundland have active radars which are constantly on. Lastly, a final assumption is that technology exists which can be easily implemented for the project purposes (ie: the wheel does not have to be reinvented).

Constraints for the project include that the weather conditions are out of our control and that the only way to test the product will be in the actual atmospheric conditions. In addition, another constraint imposed upon our project is that the amount of time required to pass the proposed project pan though the Coast Guard system is longer than we will be at the Academy.

1.3 Documents Reference

"Interferometric Intrapulse Radar Receiver for Specific Emitter Identification and Direction-Finding." *DRDC Ottawa /RDDC Ottawa*. 19 Oct. 2007. <http://www.ottawa.drdc-rddc.gc.ca/html/REW-224-iir_e.html >.

2. SPONSOR NEEDS / OPERATIONAL REQUIREMENTS

a. The system must be mountable aboard a CG HC130.

b. The system must be operable at altitudes of 5500 to 8000 ft.

c. The system must contribute to the convergence of evidence as to whether a surface target is a ship or an iceberg.

d. The system must find an accurate bearing to said surface target.

e. The system must be implemented using radar detection.

f. The system must be readily available or practical.

3. REQUIREMENTS TRACEABILITY MATRIX

Level	Need	Functional Requirement	Justification
1.		**Functionality**	
1.1	a.	A visual interface with a numerical bearing of radar contacts which is usable by a trained Coast Guardsman.	User-friendly interface inside the HC130
1.2	c. & e.	Detect X-band and S-band radar signals	These signal types cover the marine navigation frequency bands used in the Grand Banks.
1.3	b.	Operable at altitudes of 5500 to 8000 ft.	This is the operating altitude of the HC-130 airframe
1.4	d. & f.	Must be attainable and testable.	Canada has a directional radar detection system.
2.		**Performance**	
2.1	b.	Operable at altitudes of 5500 to 8000 ft.	This is the operating altitude of the HC-130 airframe

APPENDIX D: Support Plan

Iceberg Differentiation

SUPPORT PLAN

December 3rd, 2007

By: Abigail Lafond & Bryan Weber

Purpose:

The International Ice Patrol (IIP) flies hundreds of hours annually over the Grand Banks of Newfoundland performing iceberg reconnaissance in Coast Guard HC-130 aircraft. Weather conditions on the Grand Banks, including thick fog (70% to 80% of the time) and low cloud ceilings, seldom afford opportunities for visual reconnaissance. Due to the foul weather conditions the planes often have to dive below the normal operating altitude (5500-8000 ft) to 400 ft. These dives, taking between half an hour to an hour, are often a waste of resources, as a deviation does not necessarily mean positive or negative iceberg identification.

As a result of the low visibility in the area, IIP relies heavily on radar systems, including the APS-137 (made by Raytheon) Forward Looking Airborne Radar (FLAR) and APS-135 (made by Motorola) Side Looking Airborne Radar (SLAR), as well as other sensors, including Automatic Identification System (AIS), to detect surface targets, and classify them as icebergs or ships. Unfortunately, a large number of the ships on the Grand Banks during the iceberg season are small fishing vessels that are not required to carry AIS, making such differentiation very challenging. The IIP requests a cost beneficial system which will not be affected by adverse weather conditions, will allow for the distinction between fishing vessels and icebergs, and will accurately provide the positions of these objects using radar signal detection.

Design Solution:

In conjunction with the Deepwater project, the United States Coast Guard has chosen EDO's ALR-95(V) maritime patrol system to be incorporated into the CASA and the C-130J airframes. The Coast Guard has a requirement for the new C-130J airframes to have Electronic Support Measures (ESM) capability. The EDO Corporation has a contract with the Coast Guard to supply their radar detection system the ALR-95(V) on the new J-model planes. However there is no requirement or plan to support the older H-model, used by the IIP, with such equipment. Although the IIP needs the Electronics Intelligence (ELINT) equipment, the old H-model will eventually be replaced by the J-model, so updating old airframes may not be cost beneficial.

The design solution will be the plan we as the researchers will follow to ensure that the IIP's needs are incorporated into the future plans of the Coast Guard. Four main steps will be completed in the design process, as seen in the attached flow chart. The four steps are to find

existing technology, test the technology, revise the technology, and then to perform a cost analysis.

The first step is to find existing radar signal detection technology. So far, we have found the ALR-95 (V), which is being incorporated in the Coast Guard's Deepwater project. The Canadian government is currently conducting top secret research on radar signal identification technology, but this is not a technology that is fully developed, accessible, nor manufactured at this time. The Navy has used the ALR-66B(V)3 in the past and the functions are similar to that of the ALR-95(V). The ALR-95(V) is newer. The Navy is currently in the process of replacing their ALR-66B(V)3's with ALR-95(V)'s. The Navy is keeping the direction finding portion of the ALR-66B(V)3's, so gaining their old systems is not an option.

The second phase of the design will be the testing of the ALR-95 (V) model. We are trying to lease, buy or somehow acquire an ALR-95(V) to install here in Macalister Hall and do some testing on the river. Another option is that the Coast Guard might have the ALR-95 (V) ready for a test flight in March of 2008. The ALR-95 (V) will hopefully be installed with all of the components on a C-130 in Elizabeth City and will fly with the IIP for testing.. We need to develop a test plan, so that we can fly with the IIP and see if the ALR-95 (V) will be a system that will help with the ice patrols. One design idea is to ask a Coast Guard cutter (maybe an 87' patrol boat) to emit S- band and then later X-band radar signals while we take measurements from Macalister Hall or the C-130 (equipped with the ALR-95 (V) system) flies overhead. When the ship is at various azimuths and angles to the plane reliability and detectability can be calculated. One consideration that should be observed should be manpower used to operate the system.

The third phase of the design will be to revise the tested ALR-95 (V) model for the needs of the IIP. Three things must be considered in revision. First, the test results need to be analyzed to see if the ALR-95 (V) meets the needs of the IIP in its current state in terms of mission execution. If not suggestions need to be formed to modify the system so that it fits the needs of the IIP. Secondly, the airframe aerodynamics and weight placement must be confirmed for the current system and for any design modifications. Lastly, the documentation of the Coast Guard's Deepwater project involved with the ALR-95 (V) needs to be analyzed. The business case, requirements, specifications…of the Coast Guard need to be compared to those we drew up for the IIP. The ALR-95 (V) must be analyzed to see if it meets the needs it was contracted for by the Coast Guard, and in addition the needs of the IIP drawn up by us. So far, it is looking like the IIP missed putting their requirements into the Deepwater plans.

The fourth phase of the design is to consider the timing and costs of all available options. There are three known options at this time. The first is to use the ALR-95 (V) for IIP missions and to wait until the IIP gets the new J-model airframes. The second is to use the ALR-95 (V) for

IIP missions and to install the system on the old H-model airframes. The third is to use a modified version of the ALR-95 (V) for IIP missions and install the system on the old H-model airframes.

All test results will be presented to the IIP, as well as all of the pros and cons in regards to cost and timing of each solution. Throughout the design process the IIP will be updated on the politics and progress made not only by the researchers, but also by the Coast Guard as a whole.

The main focus we will take is to develop and hopefully create a test plan for the ALR-95(V) incorporating the mission needs of the IIP. Although the above four steps will be accomplished, that is in an ideal situation. Realistically, we want to develop a test plan and hopefully be able to test an actual ALR-95(V).

Support Considerations:

Economic:

The ultimate funding for a radar signal detector will come from the Coast Guard Budget. Funding can be obtained from the Electrical Engineering department and also from the IIP as needed for the research associated with this project. We need to ask for money as we need it because we essentially have no budget; we have to ask for individual items. The more we can show what the capabilities are of the ALR-95(V), the more likely it will gain funding. If we can tie the capabilities of the ALR-95(V) to other Coast Guard applicable missions, the system should gain more funding support.

Manufacturability:

The system will be contracted out to a manufacture. The ALR-95(V) is built by ITT Corporation. Another comparable system is the ALR-66B(V)3, but the focus of this project will be on the ALR-95(V).

The ALR-95(V) system will be placed on the new C-130J models when funding becomes available. This project will decide if the ALR-95 (V), a similar company's product, or no system (in the case that the IIP will be getting J-models) should be placed on the older H-model airframes.

Concerns with timing must be considered. If the IIP will be using the new J model in the future, it may not be cost beneficial for the Coast Guard to temporarily place a radar detection system on the older H-model airframes.

The needs of the IIP in relation to the needs given to Deepwater from the Coast Guard must be considered. The product already being manufactured might have to be revised to meet the needs of the Coast Guard and the IIP.

Sustainability and Reliability:

The IIP wants another tool to use for the convergence of evidence used in determining if a target on active radar is an iceberg or a boat. If a radar signal is detected, the target will have evidence that it is a boat. If there is no radar signal detected, the target can not be assumed to be a boat or an iceberg. The target could be a boat which has its radar off or it could be an iceberg, as both will not emit radar signals. A signal detected will indicate a boat, but a lack of radar signal detection will not aid in the convergence of evidence.

Basic spare electronic parts are expected to be held in inventory at every Coast Guard air station. Reliability of this equipment is not life or death, so spare parts are not required to be taken on patrols. When there is a failure in the system, the affected area will be sent to the appropriate Coast Guard maintenance facility where a replacement will be sent to the IIP immediately. The maintenance facility will have spare systems on hand. A contract will be drawn up with the manufacture so that for a time period (to be determined) all the malfunctioning equipment will have a maintenance warranty.

Life-Cycle Costs:

If the ALR-95(V) is used, then it should last the lifespan of the C-130J airframe. If a modified system is used, it should last the remaining life of the HC-130 airframes. The costs of the lifecycle are not known yet, as a specific design model has not been chosen. Regardless of design, all costs will fall under the Coast Guard's budget.

External Considerations:

Environmental:

There is no known impact on the environment for radar signal identification technology. When the equipment has reached the end of its serviceable life cycle, the chosen design system will most likely be sold to another country, fixed to last longer, or be used by another government agency.

Sea state must be considered when testing design models. If there is a small boat hidden in rough seas, the chance of detecting the emitted radar signal may decrease. Various sea states should be used in testing to determine reliability of the system. Visibility and weather should not affect the system reliability because radar signals are not weather dependant.

There are no specifically known Federal or State regulations on radar signal detection, but there are agencies that govern this in the spectrum management office of DHS as well as CG(6)-22 office of spectrum management. A system can not interfere with FAA navigation systems. If a ship is broadcasting a signal, they have no right to privacy for any information which can be derived from the signal.

Health and Safety:

There are no known health and safety concerns associated with radar signal detection.

Ethical, Social & Political:

Political concerns surround the design, acquisition and funding of the entire project. Deepwater has decided to use the ALR-95 (V) for the new C-130J models. Should the IIP decide to use the same model, they will have to wait for funding for the entire new J model airframes, or for just a variation of the ALR-95 (V) system package. Choosing a different system than the ALR-95 (V) will be difficult, as compatibility of aircrafts across the Coast Guard is an issue. The Coast Guard as a whole may mandate that the IIP not install a different radar signal detector than the ALR-95 (V), as it has already been chosen by the Coast Guard Deepwater project. If the IIP were to use the ALR-95 (V) maintenances would be easier than if an entire different system was implemented.

Software Considerations:

Privacy:

Software incorporated with the ALR-95 (V) (or other chosen system) needs to be explored for its ability to maintain its correct level of classification. ELINT is often classified and the radar signals collected with the ALR-95 (V) will need to classified due to the fingerprinting associated with the database built in the system. The IIP doesn't need the specific emitter identification (SEI) capability for fingerprinting, as the IIP only needs to know that the target is a ship, not specifically what ship.

Security

Software incorporated with the ALR-95 (V) (or other chosen system) needs to be explored for its ability to maintain its correct level of classification. ELINT is often classified and the radar signals collected with the ALR-95 (V) will need to classified secret due to the fingerprinting associated with the database built in the system. The IIP doesn't need the specific emitter identification (SEI) capability for fingerprinting, as the IIP only needs to know that the target is a ship, not specifically what ship. If another system other than the ALR-95 (V) is used, there is a chance that the collected data won't need to be classified. The collected signal should not have a way of being tampered with. If a signal is emitted and the location of emission derived, there must be something in the water at that location with an active radar.

APPENDIX E: Specific Technical Background

Iceberg Differentiation

Specific Technical Background

January 25th, 2008

By: Abigail Lafond &Bryan Weber

When a radar signal sent from a vessel into the atmosphere, the signal looks like $s(t) = x(t)\cos(w_c t) - y(t)\sin(w_c t)$. This is the same signal that is coming into the receiver on an aircraft (with added noise). The signal enters one channel of an antenna array and undergoes IQ demodulation to sort the signal into its I (in-phase) and Q (quadrature) components. This sorting is done to determine how much of each signal is projected in each plane, as seen in Figure 1.

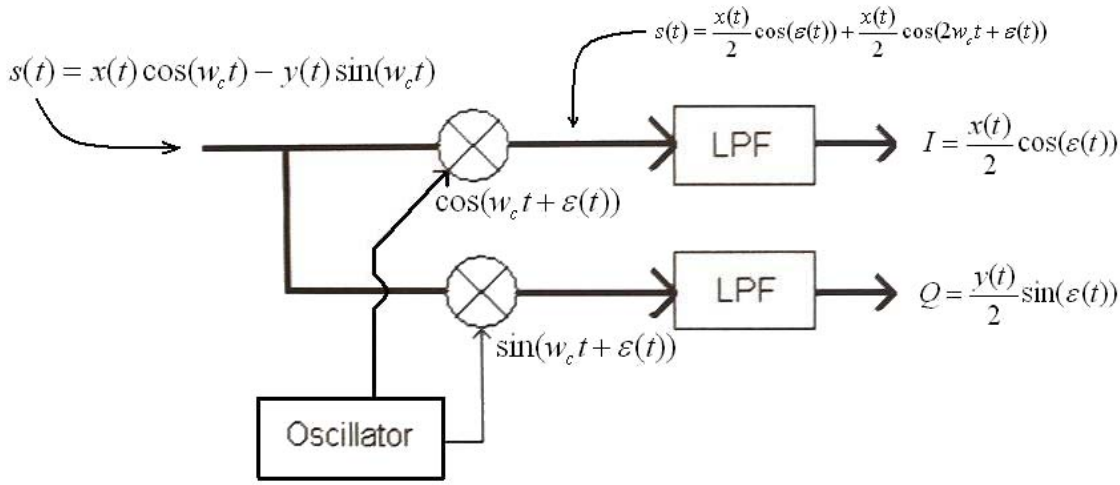

Figure 1: IQ Demodulation Block Diagram

The signal is first mixed separately with a $\cos(w_c t + \varepsilon(t))$ and then with a $\sin(w_c t + \varepsilon(t))$. The two components have the same phase shift because they stem from the same oscillator in the receiver on the aircraft. The receiver doesn't necessarily have the same phase shift as the transmitter. The difference between the receiver and the transmitter is constant, resulting in a phase lock. This difference in phase reveals itself in the IQ plot, like in a moving plot of Figure 2. The signal vectors will be locked in phase relative to each other, but will rotate at a constant rate equal to the phase difference around the center.

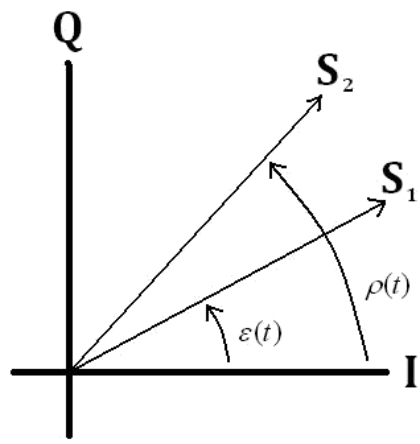

Figure 2: IQ Signal Plot

Looking at strictly the I component, the signal $s(t) = x(t)\cos(w_c t) - y(t)\sin(w_c t)$ is mixed with $\cos(w_c t + \varepsilon(t))$ and the result is $s(t) = \frac{x(t)}{2}\cos(\varepsilon(t)) + \frac{x(t)}{2}\cos(2w_c t + \varepsilon(t))$ due to the trigonometric property $\cos(a)\cos(b) = \frac{1}{2}\cos(a-b) + \frac{1}{2}\cos(a+b)$ as well as $\cos(x) = \cos(-x)$. The lower portion of the equation gets filtered out by the low pass filter (LPF), as the signal is taken to baseband and the secondary portion lies past the transition band. After the LPF, the portion of the signal projected in the I plane is $I = \frac{x(t)}{2}\cos(\varepsilon(t))$. The same calculation can be done again, only this time mixing with $\sin(w_c t + \varepsilon(t))$ to get $Q = \frac{y(t)}{2}\sin(\varepsilon(t))$. The IQ vector is plotted on the IQ plane, as previously seen in Figure 2.

The IQ demodulation calculation needs to be completed for each channel in an antenna array. Not all of the signals ($s(t)$) will have the same phase difference of $\varepsilon(t)$, even though the signal is technically coming from the same vessel. The in coming signal into the demodulator might have a phase shift that includes $\rho(t)$. Regardless, the same IQ calculations can be used to find the different signals at each channel of the antenna.

DREO designed their IIR system with four cavity backed antennas in an "L" shape configuration on the wingtips, as seen in Figure 3. Due to differences in wavelength (λ) for S

Figure 3: Convair 580 with 4-Channel Digital Radar Signal Receiver [9]

band and X band, the larger "L" collects S band signals (λ=8 to 15 cm), while the smaller "L" gathers X band signals (λ=2.5 to 4cm). The shape of the radar signal receiving antenna is very important in determining the timing between the various radar pulses.

The antenna array for an X-band signal can be seen in Figure 4. Notice that there are

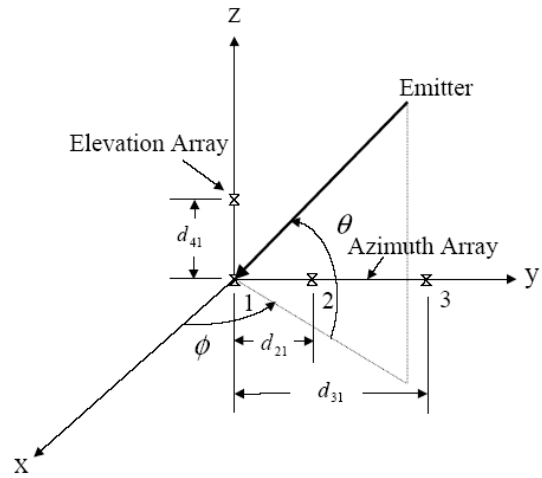

Figure 4: Geometry of the Azimuth and Elevation of an X-Band Antenna Array [9]

three antenna arrays in the azimuth plane, and two antenna arrays in the elevation plane. The azimuth plane has three antenna elements as opposed to the two in the elevation plane, giving better accuracy. This is shown to be true in test results conducted by DREO with a stationary unit achieving an angle of arrival error of .30 in azimuth and .88 in elevation [9]. The reason azimuth is more accurate than elevation is due to the mathematics and concepts behind having three elements instead of two for direction finding.

A signal colliding with the wingtip enters channel 1 at a fraction of a second different then the signal enters channel 2 and 3. Based on Fourier analysis, a time delay is a shift in phase. This phase difference can be seen when comparing the number of lobes compared to the distance between the elements. For two elements spaced at a distance of $\frac{\lambda}{2}$, two wide lobes are created, as seen in Figure 5. As the distance between the two elements increases, the number of different

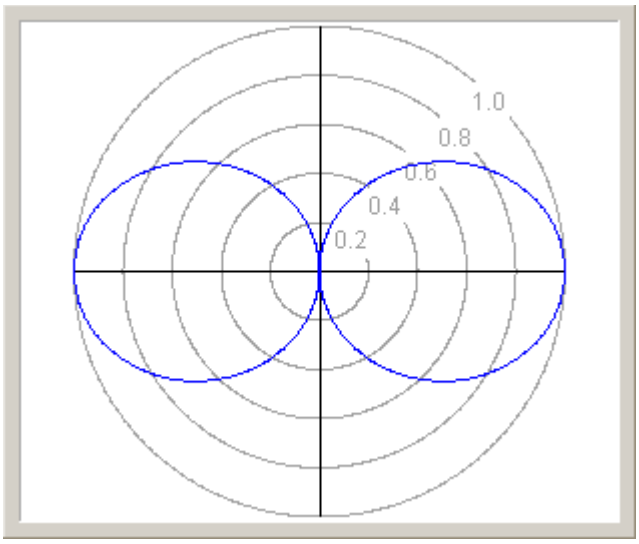

Figure 5: Radiation For Dipole of Distance of $\frac{\lambda}{2}$(linear) [10]

directions that the signal could be coming from increases. The lobes become skinnier as they become more numerous in Figure 6. If element 1 is used for both of the distances, then the

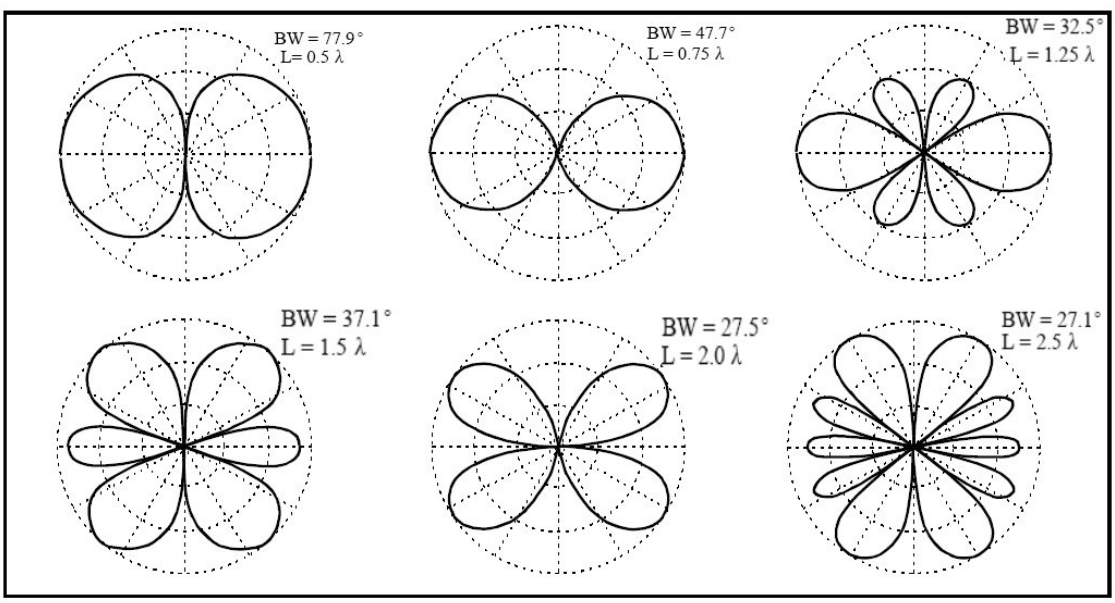

Figure 6: Dipole Antenna Radiation for Varying Lengths [11]

lobes from both graphs can be overlaid, compared to find the general direction of the signal and then fine tuned to a more specific direction of the signal. The short 1,2 component can be used to determine the initial direction of the signal, as there are fewer choices of lobe directions for a short element when compared to a long one. That direction can then be applied to the larger 1,3 component. The lobe on the longer 1,3 component which most closely matches the chosen one from the 1,2 component tells a more accurate direction of the signal [12]. The elevation antenna does not have this fine tuning capability, because there is only two channels to compare, instead of three channels. DREO's design requirements did not need a more accurate elevation angle.

The IQ demodulation can be used to tell the direction of the lobe revealing the bearing to the vessel emitting the signal. When all of the signals are plotted in the IQ coordinate system, the variations in phase between the signals can be observed. These phases can be subtracted from one another to obtain the direction of the optimal lobe. Looking again at Figure 2, if the phases for channel 1 and 2 were compared, the direction of the incoming signal would be at $\varepsilon(t) - \rho(t)$, and would correspond to the correct directional lobe in Figure 5.

Once the direction of one signal is found, an aircraft can lock onto that signal and compute the direction multiple times as it flies through the atmosphere. DREO plotted the bearings determined for a signal in Figure 7, and used the method of least mean squares to determine the latitude and longitude of the signal emitting vessel. The method of least mean squares takes all of the signal bearing data and reduces down the variables to map a bearing at a certain time onto a two dimensional latitude and longitude plot. The x's in Figure 8 show the position of the sensor, as the airframe flies over the target of interest. The convergence of all of the red lines indicates the exact latitude and longitude of the signal emitting vessel.

The United States Coast Guard should acquire an interferometric system similar to that developed by DREO. Interferometric capabilities would greatly enhance the mission capabilities of the Coast Guard. The locations of fishing vessels, as well as vessels in distress could be determined. An initial investment for modern technology could save the service money as well as lives.

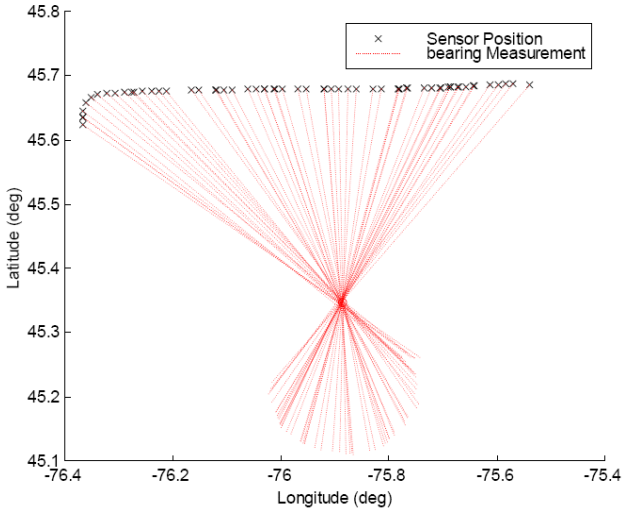

Figure 7: Geolocation of a stationary Radar Emitter [9]

Two other systems that can determine a bearing to a radar signal are the AN/ALR-95(V) and the AN/ALR-66. The AN/ALR-95(V) is currently being acquired by Coast Guard Deepwater and is being installed on the CASA airframe. The Navy is also purchasing the AN/ALR-95 for its P-8 airframe as it disposes of the antiquated AN/ALR-66. Both systems are able to fingerprint specific radars using signals intelligence. All radars have their own signal fingerprint number which can be looked up in a classified manual. The name of the vessel can then be identified and stored with the signal in a library for future comparison. The old AN/ALR-66 had a feature where the user could set certain signals as high interest and then when these were detected, they would be "accompanied by both an audio and visual alarm to alert the operator to their detection" [13]. The AN/ALR-95(V) improves upon the AN/ALR-66 by extending "the existing SEI and manual ESM support capability on the AIP aircraft by the addition of automated Wideband Signal Acquisition and Threat Warning functions" [13]. The AN/ALR-95(V) system can be seen in Figure 8. The system is similar to the aforementioned Canadian System, as there are wingtip receivers, but there is also a spinning DF antenna seen in Figure 8. The spinning dome antenna is located on the belly of the airframe and "covers the 0.5

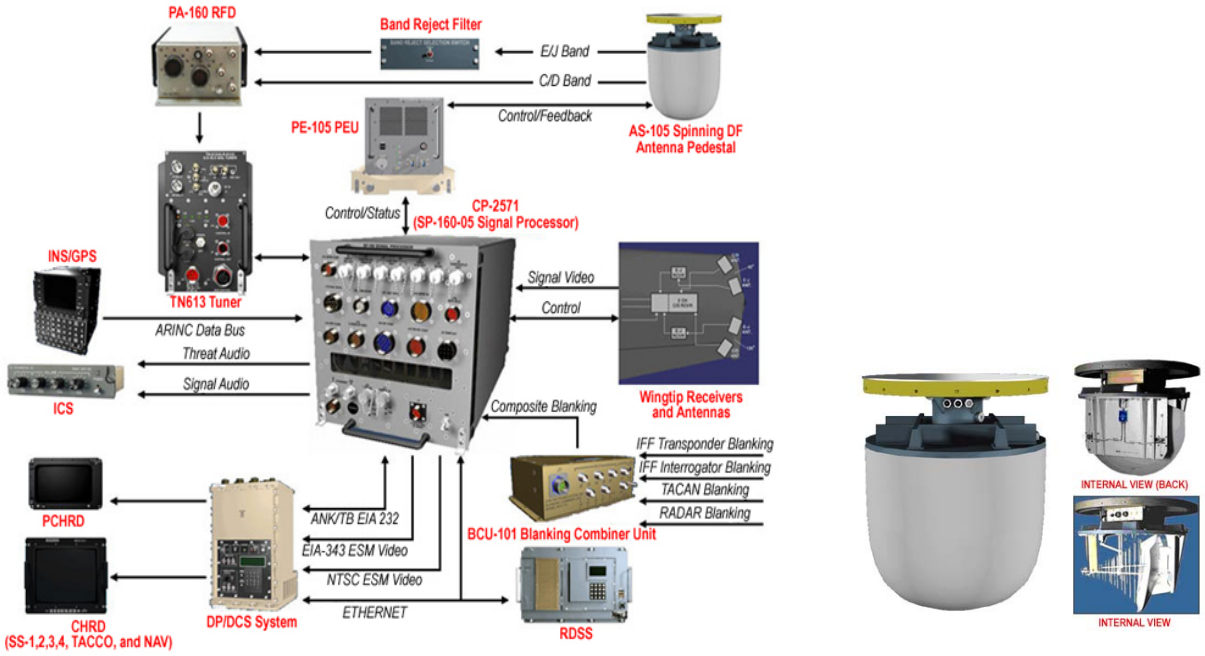

Figure 8: AN/ALR-95(V) System [13]

to 18 GHz range in two bands, 0.5 to 2 GHz (vertically polarized) and the 2 to 18 GHz (horizontally polarized)" [13]. These ranges are satisfactory in covering the S band (2.3-2.5and 2.7-3.7 GHz) and X band (8.5-10.68 GHz) band shipboard radars [8]. The main difference between the wingtips and the spinning DF antenna is that the wingtips use interferometry with signal approach angles to determine the bearing to an object whereas the spinning DF antenna uses timing differences to determine the bearing to an object [12].

APPENDIX F: Test Plan

Iceberg Differentiation

TEST PLAN

March 4th, 2008

By: Abigail Lafond & Bryan Weber

Joint Navy/Coast Guard ALR-95(V) Test Plan

Synopsis

I. Ice Patrol Mission Test and Evaluation purpose:

The International Ice Patrol (IIP) has sponsored a cadet project at the United States Coast Guard Academy to research and recommend a radar detection and direction finding device for potential installation on the new CG C-130J airframe. This technology will be used to differentiate between icebergs and vessels and ultimately provide safe transit for trans-Atlantic shipping in the vicinity of the Grand Banks of Newfoundland. Three crucial points are the practicality and cost of the system, as well as the fact that IIP does not require identity information on a specific vessel, but rather that there is a vessel and not an iceberg on the surface.

If a contact is detected on an active radar (a radar that sends and receives a signal), IIP might not be able to tell, even with the many tools they have available, if the target is an iceberg or a vessel. Consequently, IIP often has to deviate from the search pattern to descend below the clouds to visually classify the target. If a radar direction finder were installed on the airframe, IIP could determine whether or not the active target correlates with the signal. If there is correlation, then there is no need for a visual confirmation and the use of extra time and fuel to descend below the clouds. If there is no signal detected for an active radar target, IIP cannot automatically assume that the target is an iceberg. Fishing vessels may have their radars turned off, causing them to appear as icebergs, and therefore a visual identification may still be required. After extensive research, the ALR-95(V) has been selected for further testing to determine whether or not the system meets the requirements of the IIP and can be integrated on the C-130J platform.

II. International Ice Patrol (IIP) Background:

The U.S. Coast Guard is tasked by US Code to conduct the North Atlantic Ice Patrol, as required by the SOLAS international treaty. IIP performs iceberg reconnaissance in Coast Guard HC-130 aircraft, flying hundreds of hours annually over the Grand Banks of Newfoundland. The Labrador Current carries icebergs south along the coast of Canada onto the Grand Banks and the great circle shipping lanes. IIP uses the data acquired from their patrols to place the discovered icebergs on charts. From this information IIP can draw a virtual line in the ocean to alert vessel traffic as to where these icebergs are located. This line is called the Limit of All Known Ice (LAKI). If the LAKI is drawn too far south, vessels must travel longer routes, which are more costly.

Despite having ice observers positioned at the windows of the airframe, IIP relies heavily on active radar systems as a result of the frequent low visibility conditions on the Grand Banks. The radar systems currently used by the IIP are both active and include the Raytheon APS-137 Forward Looking Airborne Radar (FLAR) and the Motorola APS-135 Side Looking Airborne Radar (SLAR). The FLAR uses active radar to track objects and determine their course and speed. The types of objects that the system tracks range from vessels, to icebergs, to debris in the water.

The SLAR is an active radar that detects objects and records their position on a waterfall display. The SLAR is very effective for icebergs larger than fifteen meters. The best way to determine whether an object is a vessel or an iceberg is to use the Inverse Synthetic Aperture Radar (ISAR) mode of the APS-137.

The SLAR and the FLAR are not effective enough for IIP's purposes to be considered standalone systems. They can determine the positions of surface contacts, whether they be vessels, icebergs, or any other kind of contact, but they cannot reliably characterize those contacts to be of one type or another. In other words, they are insufficient at determining whether a contact is a vessel or not.

Personnel

I. Team Members:

Project Sponsor: International Ice Patrol

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Phone: (908) 229-6437
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II. Units:

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POC: CDR William Brown
Operations Officer
Commander, Patrol and Reconnaissance Wing FIVE
Phone: 207-921-2265
E-mail: william.d.brown@navy.mil

The number of people required at NASB for the actual test is left to the discretion of the command. Aircraft system operators are needed and the team members will be the data recorders. Most importantly, NASB will be supplying the aircraft equipped with the ALR-95(V) and active radar.

Sector Northern New England (SNNE), ME

POC: LT Brent Yezefski
Chief, Response Branch
Phone: (207) 741-5491
E-mail: Brent.c.yezefski@uscg.mil

The number of people required from SNNE is dependant on the type of vessel available for testing and left to the discretion of the command. The normal crew size will be sufficient for testing.

Procedure

I. Location:

Test Site - Gulf of Maine
SNNE – South Portland, ME
NASB – Brunswick, ME

Three rough areas of operation and suggested track line ideas are included in Figures 1-3. These maps are not intended for literal use, but merely to give a rough idea of the kind of area we want to cover.

Only one final plan needs to materialize out of the three suggestions. SNNE will determine the trackline of their vessel since their range will be the limiting factor for the AOR. There are two things SNNE should consider when determining their track. First, the test results should not vary with the presence of land or other vessels in case SNNE wants to stay close to land. Lastly, we should be conscious of disturbing the natural everyday occurrences in the Casco Bay area with the noise from the C-130. The POC at SNNE will inform the other POCs of the intended track by 1600 17MAR08.

Based on the vessel's track, NASB will overlay their intended flight path above that of the vessel. The vessel should follow their intended track as closely as possible, so that the aircraft can easily find the vessel. However, the aircraft may deviate from their proposed track based on the needs of data collection. The idea is to find the range limits which the ALR-95(V) can still 'see' the surface contact and then stay within those limits to collect data. The range limit and

data collection will need to be conducted for two altitudes: 5500 ft and 8000 ft (in theory, down the track at one altitude and back at the other). If these altitudes are too large for the ALR-95(V) to 'see' the contact, then the highest altitude possible should be noted and used for testing.

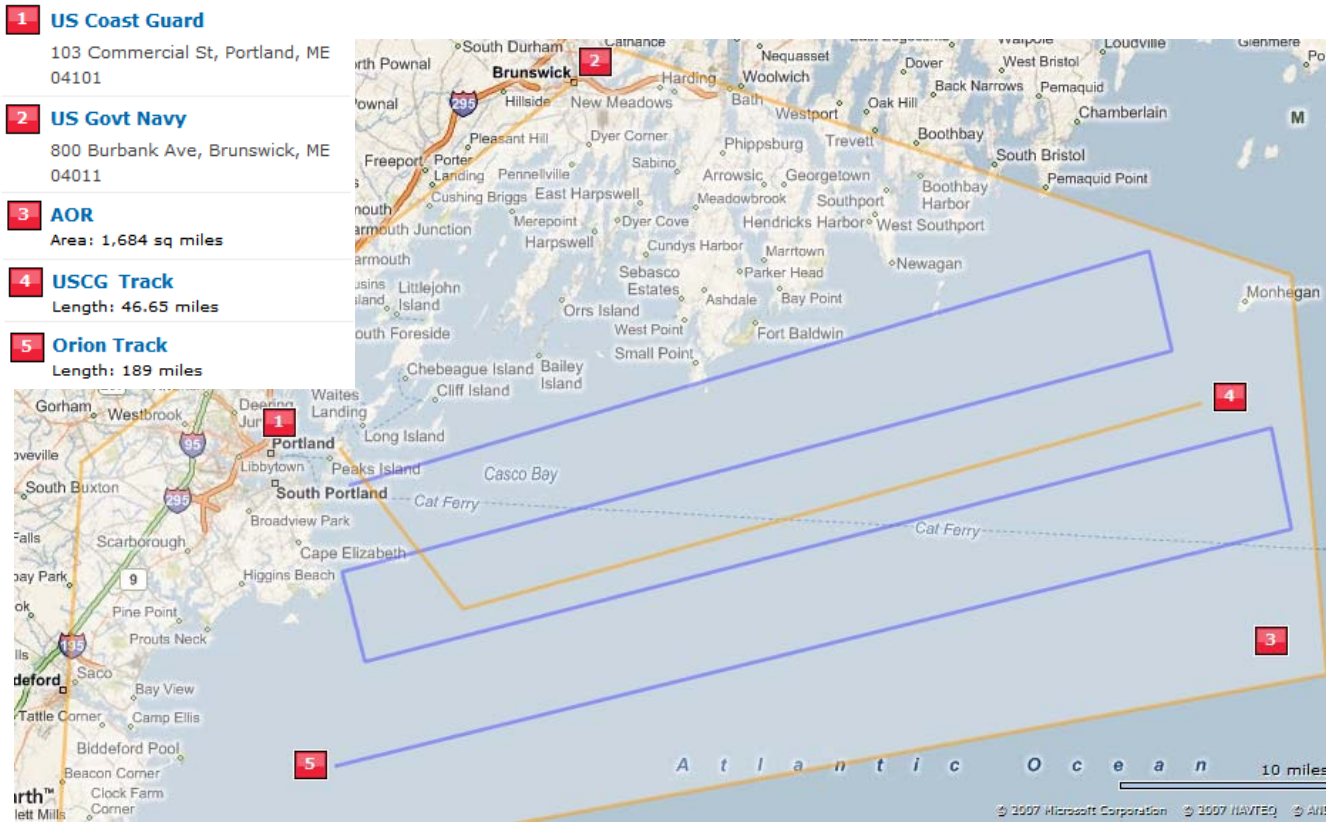

Figure 1: Proposal #1

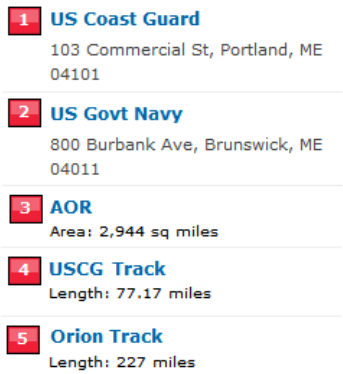

Figure 2: Proposal #2

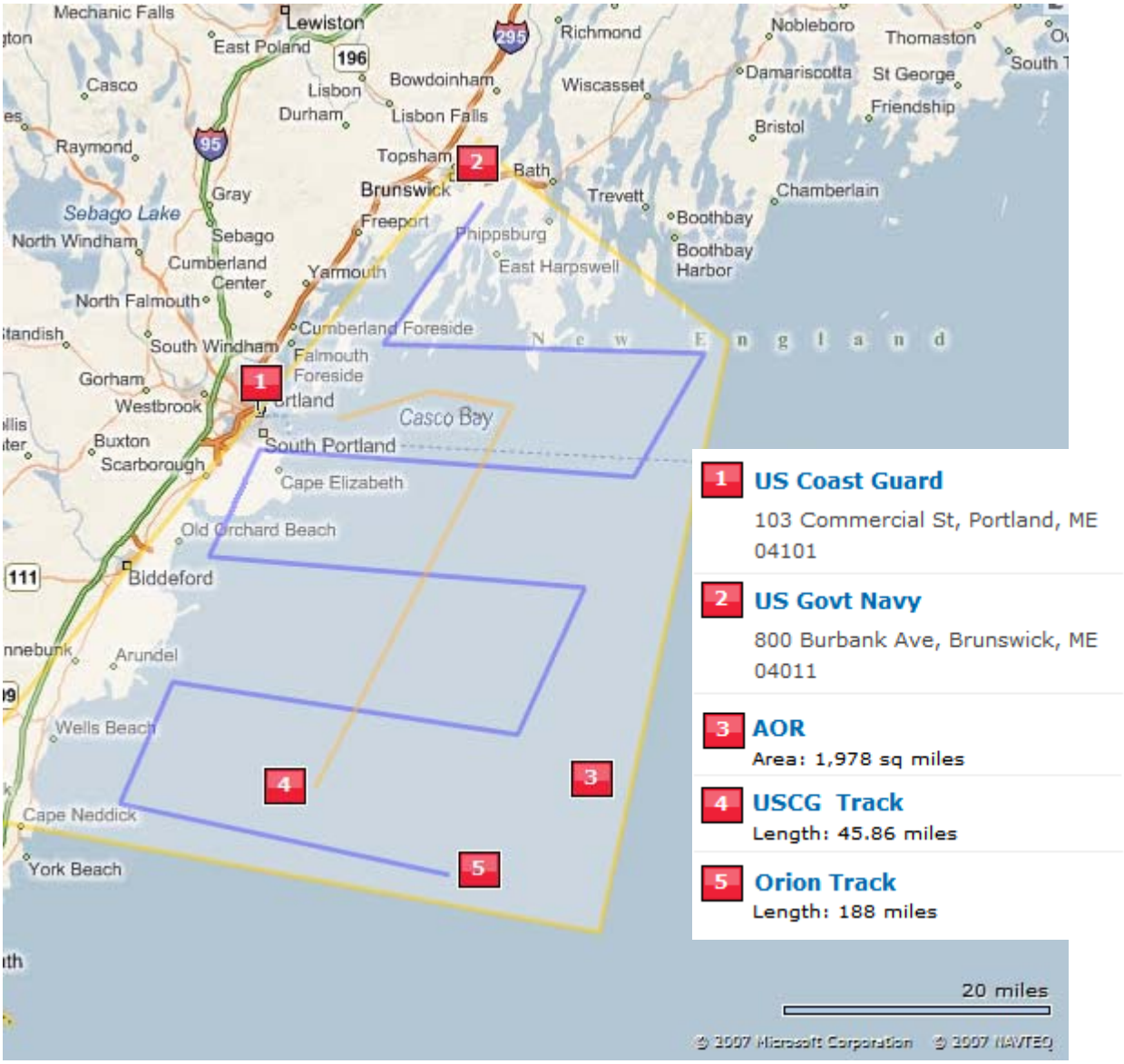

Figure 3: Proposal #3

II. Time schedule:

a. Monday 31 Mar 08
   - Leave USCGA for Maine (about 4 hours to Portland)
   - Meet with SNNE (time to be determined)
   - Meet with NASB (time to be determined)
   - Travel to lodging

b. Tuesday 1 Apr 08 (Test date)
   - CG vessel leaves Portland
   - P-3 leaves NASB
   - Test on site for 4 hours
   - Assets return home or continue patrol
   - Debrief with NASB
   - Debrief with Sector (or next day)

c. Wednesday 2 Apr 08 (Backup test date)

d. Thursday 3 Apr 08
-Travel to CGA

III. Overview

Group members will meet with SNNE and NASB individually on 31MAR08 to make sure testing will run smoothly, stopping in Portland first, and then continuing on to Brunswick. Safety concerns will be discussed, to ensure that everyone involved in the test and in the surrounding area will remain safe before, during, and after the testing.

The POC at NASB and at SNNE will agree on a VHF frequency channel for communication by 1600 25MAR08. Two back up frequencies will also be established.

The test date will depend upon two factors; the weather conditions and the availability of assets. If the weather would place the operators in danger, then the test must wait for the backup date. NASB will do their best to maintain a backup date. If Navy or CG assets are needed elsewhere for an actual mission, or a maintenance issue arises, the test will instantly take second priority.

IV. System Configuration:

a. P-3 Orion
   1) Pen and data sheets for recording data.
   2) Memory stick to store unclassified screenshots from the ALR-95(V).
   3) ALR-95(V): provides Latitude/ Longitude of surface contact and bearing to surface contact.
   4) Active radar (preferably the APS-137): provides Latitude/ Longitude of surface contact and bearing to surface contact.
   5) GPS Receiver: Provides precise time to sync with CG vessel data used for analysis as well as Latitude/Longitude of aircraft.
   6) Altimeter: Provides altitude of aircraft.

b. CG Vessel
   1) Actual location of vessel recorded in navigation software exported to an excel spreadsheet. The data needs to have Latitude/Longitude at certain GPS synced times.
   2) Size of vessel is at the discretion of SNNE

Initial Set-up

The POC from SNNE will decide what time is feasible to leave the pier and inform the other POC's by 25MAR08. The P-3 will take off about 1 hour after the CG vessel has been confirmed leaving Portland via the established VHF frequency or phone. NASB will reserve a 4 hour on-station block for testing.

Test Layout

I. Objective:

To test the functional requirements that the IIP requires of the ALR-95(V) for the mission of iceberg reconnaissance.

II. Sponsor Needs/ Operational Requirements:

a. The system must be mountable aboard a CG C-130 (not tested in this plan).
b. The system must be operable at altitudes of 5500 to 8000 ft.
c. The system must contribute to the convergence of evidence as to whether a surface contact is a ship or an iceberg.
d. The system must find an accurate bearing to said surface contact.
e. The system must be implemented using radar detection.
f. The system must be readily available or practical.

III. Test Overview:

On the morning of the test, the CG vessel will depart the pier in Portland, ME. One hour later, the P-3 Orion will take off from NASB for the Gulf of Maine with the research team on board. The aircraft will collect data on any available local vessels of opportunity until the CG asset arrives on scene to start the exercise.

At this point, both the CG vessel and the aircraft will commence the exercise and will follow their respective track lines. When the CG vessel is detected, the plane will sweep the area over the vessel, noting when the vessel is out of range of the ALR-95(V) or the active radar. The aircraft will focus its attention on the CG vessel to obtain the most accurate position possible. The test will conclude at the end of four hours on site. At this point, the Navy and CG vessels can decide whether to continue their patrols or return home. Upon landing, the team will debrief with the aircraft crew. The team will debrief with the CG vessel, depending on time, that afternoon or the following day.

IV. Test Procedure:

a. CG vessel leaves Portland, ME according to the proposed trackline and informs NASB of departure via the communication plan. The exact location (lat/long) and time needs to be recorded for the vessel. This can be done continuously if there is a software track line that is downloadable to excel, or in-sync with the P-3 using GPA timing if no track line saving system is available.
b. P-3 departs NASB for AOR one hour after CG vessel leaves pier.
c. P-3 marks civilian surface contacts for their location, make/model of active radar, and takes a snapshot on the ALR-95(V) (Appendix A). The intent of this is for the group to see the various frequency capabilities of the system.
d. P-3 locates CG vessel and enters the radar signature into the ALR-95(V) database.
e. P-3 flies the proposed flight path at an altitude of 5500 ft recording as much data as possible. If the ALR-95(V) can't "see" the CG vessel, then the highest altitude possible will be used for testing.
f. Aboard the P-3, a long string of data collection will commence. On "Mark," from the test director (NASB person who is comfortable with all the equipment on board), the following data will be recorded (Appendix B):
    1) ALR-95(V): provides latitude/longitude of surface contact and bearing/range to surface contact

2) Active radar (preferably the APS-137): provides latitude/longitude of surface contact and bearing/range to surface contact
3) GPS: Provides precise time and latitude/longitude of aircraft.
4) Altimeter: provides altitude of aircraft.

g. P-3 repeats step 5 at an altitude of 8000 ft going the opposite direction down the search pattern (Appendix C). If 8000 ft is too high, then another altitude will be chosen by the test director.

h. As much data as possible should be recorded at both altitudes for the most accurate results. The frequency of data point testing will be at the discretion of the P-3 crew. Data points will change most rapidly when the target is directly below the aircraft. The group hopes to obtain a minimum of 100 data points per altitude, but more are appreciated.

i. Data collection will last for approximately four hours on scene.

V. Testing Requirements Table:

Level	Need	Functional Requirement	Justification	How Will Be Tested
1.		**Functionality**		
1.1	f.	System will have a visual interface with a geo-position for surface contacts which is usable by a trained operator.	User-friendly interface inside the airframe.	At the end of testing, the equipment operators will write down the steps taken to record data. These steps will include which buttons are pushed, and estimate of how long it took to collect data, and a reflection of how smoothly the operator thinks the process runs (including any problems encountered and potential solutions).
1.2	e.	Detect X-band and S-band radar signals.	These signal types cover the marine navigation frequency bands used in the Grand Banks.	The frequencies of other surface contacts will be analyzed to see if they fall within the required bands.
1.3	b.	Operable at altitudes of 5500 to 8000 ft.	This is the operating altitude of the C-130 airframe.	The P-3 Orion will fly the search pattern at 5500 ft and then again at 8000 ft.
1.4	f.	System must be attainable and testable.	Navy has a direction-finding radar detection system: the ALR-95(V).	Completed by conducting test.
2.		**Performance**		
2.1	b.	Operable at altitudes of 5500 to 8000 ft.	This is the operating altitude of the C-130 airframe.	The P-3 Orion will fly the search pattern at 5500 ft and then again at 8000 ft. The results will be analyzed to determine if consistent and reliable results can be obtained at these altitudes.

APPENDIX G: Cutter Location Table

Iceberg Differentiation

Cutter Handheld GPS Data Table

April 29th, 2008

By: Abigail Lafond & Bryan Weber

Latitude				Longitude				Date	Time	
N	43	32.929		W	69	51.891		4/2/2008	10:30:07	AM
N	43	32.918		W	69	51.809		4/2/2008	10:30:37	AM
N	43	32.894		W	69	51.721		4/2/2008	10:31:07	AM
N	43	32.866		W	69	51.631		4/2/2008	10:31:37	AM
N	43	32.839		W	69	51.535		4/2/2008	10:32:07	AM
N	43	32.812		W	69	51.441		4/2/2008	10:32:37	AM
N	43	32.786		W	69	51.343		4/2/2008	10:33:07	AM
N	43	32.762		W	69	51.247		4/2/2008	10:33:37	AM
N	43	32.737		W	69	51.154		4/2/2008	10:34:07	AM
N	43	32.709		W	69	51.063		4/2/2008	10:34:37	AM
N	43	32.683		W	69	50.97		4/2/2008	10:35:07	AM
N	43	32.657		W	69	50.882		4/2/2008	10:35:37	AM
N	43	32.627		W	69	50.784		4/2/2008	10:36:07	AM
N	43	32.597		W	69	50.686		4/2/2008	10:36:37	AM
N	43	32.569		W	69	50.585		4/2/2008	10:37:07	AM
N	43	32.542		W	69	50.484		4/2/2008	10:37:37	AM
N	43	32.513		W	69	50.38		4/2/2008	10:38:07	AM
N	43	32.489		W	69	50.28		4/2/2008	10:38:37	AM
N	43	32.462		W	69	50.179		4/2/2008	10:39:07	AM
N	43	32.436		W	69	50.077		4/2/2008	10:39:37	AM
N	43	32.407		W	69	49.976		4/2/2008	10:40:07	AM
N	43	32.389		W	69	49.871		4/2/2008	10:40:37	AM
N	43	32.366		W	69	49.767		4/2/2008	10:41:07	AM
N	43	32.341		W	69	49.666		4/2/2008	10:41:37	AM
N	43	32.317		W	69	49.562		4/2/2008	10:42:07	AM
N	43	32.294		W	69	49.46		4/2/2008	10:42:37	AM
N	43	32.272		W	69	49.359		4/2/2008	10:43:07	AM
N	43	32.247		W	69	49.258		4/2/2008	10:43:37	AM
N	43	32.222		W	69	49.157		4/2/2008	10:44:07	AM
N	43	32.194		W	69	49.056		4/2/2008	10:44:37	AM
N	43	32.169		W	69	48.956		4/2/2008	10:45:07	AM
N	43	32.142		W	69	48.855		4/2/2008	10:45:37	AM
N	43	32.116		W	69	48.755		4/2/2008	10:46:07	AM
N	43	32.091		W	69	48.654		4/2/2008	10:46:37	AM
N	43	32.069		W	69	48.552		4/2/2008	10:47:07	AM
N	43	32.046		W	69	48.448		4/2/2008	10:47:37	AM
N	43	32.018		W	69	48.346		4/2/2008	10:48:07	AM
N	43	31.99		W	69	48.246		4/2/2008	10:48:37	AM

N	43	31.963		W	69	48.146		4/2/2008	10:49:07	AM
N	43	31.941		W	69	48.042		4/2/2008	10:49:37	AM
N	43	31.917		W	69	47.941		4/2/2008	10:50:07	AM
N	43	31.89		W	69	47.838		4/2/2008	10:50:37	AM
N	43	31.864		W	69	47.742		4/2/2008	10:51:07	AM
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N	43	31.819		W	69	47.54		4/2/2008	10:52:07	AM
N	43	31.795		W	69	47.439		4/2/2008	10:52:37	AM
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N	43	31.684		W	69	47.049		4/2/2008	10:54:38	AM
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N	43	31.623		W	69	46.849		4/2/2008	10:55:39	AM
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N	43	31.552		W	69	46.55		4/2/2008	10:57:09	AM
N	43	31.528		W	69	46.448		4/2/2008	10:57:39	AM
N	43	31.504		W	69	46.348		4/2/2008	10:58:09	AM
N	43	31.477		W	69	46.247		4/2/2008	10:58:39	AM
N	43	31.451		W	69	46.149		4/2/2008	10:59:09	AM
N	43	31.421		W	69	46.051		4/2/2008	10:59:39	AM
N	43	31.396		W	69	45.951		4/2/2008	11:00:09	AM
N	43	31.371		W	69	45.854		4/2/2008	11:00:39	AM
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N	43	31.222		W	69	44.955		4/2/2008	11:05:09	AM
N	43	31.2		W	69	44.854		4/2/2008	11:05:39	AM
N	43	31.181		W	69	44.754		4/2/2008	11:06:09	AM
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N	43	30.96		W	69	43.664		4/2/2008	11:11:39	AM
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N	43	30.424		W	69	40.977		4/2/2008	11:25:09	AM
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N	43	30.253		W	69	40.072		4/2/2008	11:29:39	AM
N	43	30.23		W	69	39.973		4/2/2008	11:30:09	AM
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N	43	30.189		W	69	39.772		4/2/2008	11:31:09	AM
N	43	30.165		W	69	39.674		4/2/2008	11:31:39	AM
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N	43	30.136		W	69	39.473		4/2/2008	11:32:39	AM
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N	43	30.091		W	69	39.273		4/2/2008	11:33:39	AM
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N	43	30.035		W	69	39.076		4/2/2008	11:34:39	AM
N	43	30.01		W	69	38.978		4/2/2008	11:35:09	AM
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N	43	29.906		W	69	38.584		4/2/2008	11:37:09	AM
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N	43	29.849		W	69	38.39		4/2/2008	11:38:09	AM
N	43	29.821		W	69	38.29		4/2/2008	11:38:39	AM
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N	43	29.537		W	69	37.305		4/2/2008	11:43:39	AM
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N	43	29.377		W	69	36.504		4/2/2008	11:47:39	AM
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N	43	29.297		W	69	36.111		4/2/2008	11:49:39	AM
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N	43	29.017		W	69	34.775		4/2/2008	11:56:39	AM
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N	43	28.983		W	69	34.582		4/2/2008	11:57:38	AM
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N	43	28.947		W	69	34.391		4/2/2008	11:58:39	AM
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N	43	26.621		W	69	23.8		4/2/2008	12:54:11	PM
N	43	26.601		W	69	23.706		4/2/2008	12:54:41	PM
N	43	26.579		W	69	23.607		4/2/2008	12:55:11	PM
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N	43	26.542		W	69	23.415		4/2/2008	12:56:11	PM
N	43	26.525		W	69	23.32		4/2/2008	12:56:41	PM
N	43	26.506		W	69	23.226		4/2/2008	12:57:11	PM
N	43	26.485		W	69	23.131		4/2/2008	12:57:41	PM
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N	43	26.446		W	69	22.943		4/2/2008	12:58:41	PM
N	43	26.426		W	69	22.849		4/2/2008	12:59:11	PM
N	43	26.404		W	69	22.755		4/2/2008	12:59:41	PM
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N	43	26.365		W	69	22.567		4/2/2008	1:00:41	PM
N	43	26.345		W	69	22.471		4/2/2008	1:01:11	PM
N	43	26.324		W	69	22.377		4/2/2008	1:01:41	PM
N	43	26.302		W	69	22.281		4/2/2008	1:02:11	PM
N	43	26.287		W	69	22.185		4/2/2008	1:02:41	PM
N	43	26.265		W	69	22.091		4/2/2008	1:03:11	PM
N	43	26.246		W	69	22.001		4/2/2008	1:03:41	PM
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N	43	26.207		W	69	21.813		4/2/2008	1:04:41	PM
N	43	26.189		W	69	21.719		4/2/2008	1:05:11	PM
N	43	26.172		W	69	21.625		4/2/2008	1:05:41	PM
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N	43	26.104		W	69	21.237		4/2/2008	1:07:42	PM
N	43	26.081		W	69	21.144		4/2/2008	1:08:12	PM
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N	43	26.04		W	69	20.954		4/2/2008	1:09:12	PM
N	43	26.023		W	69	20.859		4/2/2008	1:09:42	PM

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N	43	25.809		W	69	19.521		4/2/2008	1:16:42	PM
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N	43	25.744		W	69	19.141		4/2/2008	1:18:42	PM
N	43	25.727		W	69	19.046		4/2/2008	1:19:12	PM
N	43	25.708		W	69	18.951		4/2/2008	1:19:43	PM
N	43	25.69		W	69	18.853		4/2/2008	1:20:13	PM
N	43	25.673		W	69	18.756		4/2/2008	1:20:43	PM
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N	43	25.476		W	69	17.601		4/2/2008	1:26:43	PM
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N	43	25.429		W	69	17.415		4/2/2008	1:27:43	PM
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N	43	25.3		W	69	16.952		4/2/2008	1:30:13	PM
N	43	25.276		W	69	16.86		4/2/2008	1:30:43	PM
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N	43	25.226		W	69	16.673		4/2/2008	1:31:43	PM
N	43	25.204		W	69	16.574		4/2/2008	1:32:13	PM
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N	43	24.773		W	69	14.856		4/2/2008	1:41:13	PM
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N	43	24.732		W	69	14.662		4/2/2008	1:42:14	PM
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N	43	24.685		W	69	14.485		4/2/2008	1:43:14	PM
N	43	24.662		W	69	14.39		4/2/2008	1:43:44	PM
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N	43	24.544		W	69	13.914		4/2/2008	1:46:14	PM
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N	43	24.233		W	69	12.663		4/2/2008	1:52:45	PM
N	43	24.205		W	69	12.569		4/2/2008	1:53:15	PM
N	43	24.185		W	69	12.474		4/2/2008	1:53:45	PM
N	43	24.163		W	69	12.373		4/2/2008	1:54:15	PM
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N	43	24.11		W	69	12.18		4/2/2008	1:55:15	PM
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N	43	24.044		W	69	11.893		4/2/2008	1:56:45	PM

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N	43	23.97		W	69	11.606		4/2/2008	1:58:16	PM
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N	43	23.929		W	69	11.416		4/2/2008	1:59:16	PM
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N	43	23.837		W	69	11.038		4/2/2008	2:01:16	PM
N	43	23.814		W	69	10.943		4/2/2008	2:01:46	PM
N	43	23.793		W	69	10.849		4/2/2008	2:02:16	PM
N	43	23.773		W	69	10.75		4/2/2008	2:02:46	PM
N	43	23.752		W	69	10.652		4/2/2008	2:03:16	PM
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N	43	23.708		W	69	10.458		4/2/2008	2:04:16	PM
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N	43	23.773		W	69	10.373		4/2/2008	2:05:16	PM
N	43	23.81		W	69	10.454		4/2/2008	2:05:46	PM
N	43	23.825		W	69	10.548		4/2/2008	2:06:16	PM
N	43	23.829		W	69	10.647		4/2/2008	2:06:46	PM
N	43	23.832		W	69	10.739		4/2/2008	2:07:16	PM
N	43	23.865		W	69	10.82		4/2/2008	2:07:46	PM
N	43	23.899		W	69	10.9		4/2/2008	2:08:16	PM
N	43	23.926		W	69	10.984		4/2/2008	2:08:46	PM
N	43	23.944		W	69	11.078		4/2/2008	2:09:16	PM
N	43	23.955		W	69	11.169		4/2/2008	2:09:46	PM
N	43	23.969		W	69	11.266		4/2/2008	2:10:16	PM
N	43	23.987		W	69	11.367		4/2/2008	2:10:46	PM
N	43	24.004		W	69	11.459		4/2/2008	2:11:16	PM
N	43	24.022		W	69	11.557		4/2/2008	2:11:46	PM
N	43	24.038		W	69	11.661		4/2/2008	2:12:16	PM
N	43	24.053		W	69	11.768		4/2/2008	2:12:46	PM
N	43	24.069		W	69	11.873		4/2/2008	2:13:16	PM
N	43	24.088		W	69	11.985		4/2/2008	2:13:46	PM
N	43	24.12		W	69	12.207		4/2/2008	2:14:47	PM
N	43	24.136		W	69	12.316		4/2/2008	2:15:17	PM
N	43	24.152		W	69	12.424		4/2/2008	2:15:47	PM
N	43	24.171		W	69	12.53		4/2/2008	2:16:17	PM
N	43	24.19		W	69	12.643		4/2/2008	2:16:47	PM
N	43	24.204		W	69	12.749		4/2/2008	2:17:17	PM
N	43	24.22		W	69	12.858		4/2/2008	2:17:47	PM
N	43	24.239		W	69	12.967		4/2/2008	2:18:17	PM
N	43	24.259		W	69	13.076		4/2/2008	2:18:47	PM
N	43	24.275		W	69	13.179		4/2/2008	2:19:17	PM
N	43	24.294		W	69	13.286		4/2/2008	2:19:47	PM
N	43	24.314		W	69	13.398		4/2/2008	2:20:17	PM
N	43	24.33		W	69	13.509		4/2/2008	2:20:47	PM

N	43	24.344		W	69	13.608		4/2/2008	2:21:17	PM
N	43	24.358		W	69	13.712		4/2/2008	2:21:47	PM
N	43	24.378		W	69	13.811		4/2/2008	2:22:17	PM
N	43	24.397		W	69	13.916		4/2/2008	2:22:47	PM
N	43	24.417		W	69	14.023		4/2/2008	2:23:17	PM
N	43	24.432		W	69	14.13		4/2/2008	2:23:47	PM
N	43	24.447		W	69	14.237		4/2/2008	2:24:17	PM
N	43	24.471		W	69	14.334		4/2/2008	2:24:47	PM
N	43	24.486		W	69	14.443		4/2/2008	2:25:17	PM
N	43	24.502		W	69	14.55		4/2/2008	2:25:47	PM
N	43	24.51		W	69	14.656		4/2/2008	2:26:17	PM
N	43	24.516		W	69	14.762		4/2/2008	2:26:47	PM
N	43	24.518		W	69	14.795		4/2/2008	2:26:56	PM

APPENDIX H: Design Specification

Iceberg Differentiation
DESIGN SPECIFICATION
18 April 2008

Revised 01MAY08

Purpose:

The International Ice Patrol (IIP) has sponsored a cadet project at the United States Coast Guard Academy to research and recommend a radar direction finding device to be installed on the CG C-130J airframe. Such a device would be used to differentiate between icebergs and vessels in the Grand Banks of Newfoundland. If a contact is detected on active radar, IIP might not be able to tell if the contact is an iceberg or a vessel, even with the many tools they have available. Consequently, IIP is often forced to deviate from the search pattern to dive below the thick clouds to visually detect the target, costing the Coast Guard $14,237 per hour of operation. If a radar direction finder were installed on the airframe, IIP could read the bearing to the target from the signal receiver and could possibly determine whether or not the active target correlates with the signal. If there is correlation, then there is no need for a visual confirmation and the use of extra time and fuel to descend below the clouds. If there is no signal detected for an active radar target, the IIP cannot assume that the target is an iceberg. Fishing vessels may have their radars turned off, causing them to appear as icebergs, and therefore a visual identification may still be required. IIP does not need to know specifics (using Specific Emitter Identification (SEI) technology) about the vessel, but rather that the contact is a vessel.

Design Solution:

The design solution chosen by USCGA for IIP was the ALR-95(V) system manufactured by ITT Company. There are slight variations of this system which differ for specific airframes. The system discussed in this design solution is the variation designed for the CG CASA airframe, despite the fact that the one tested for this project is the variation on the NAVY P3-Orion. The major difference between the two systems is that the NAVY uses wingtip antennas and a spinning DF antenna, while the CASA only has the spinning DF antenna. The manufacturer has assured the researchers that the accuracies of the two different systems are comparable.

The system will be discussed in three sections: hardware, user interface, and SEI.

Hardware

The system consists of pallet mounted and airframe mounted equipment. The pieces that are permanently attached to the airframe are the Radome and AS-106-27 Omni/DF antenna mounted on the underside of the fuselage and the PA-160-03 RF Distribution unit which mounts near the antennas. The schematic of the entire system can be seen in Figure 1

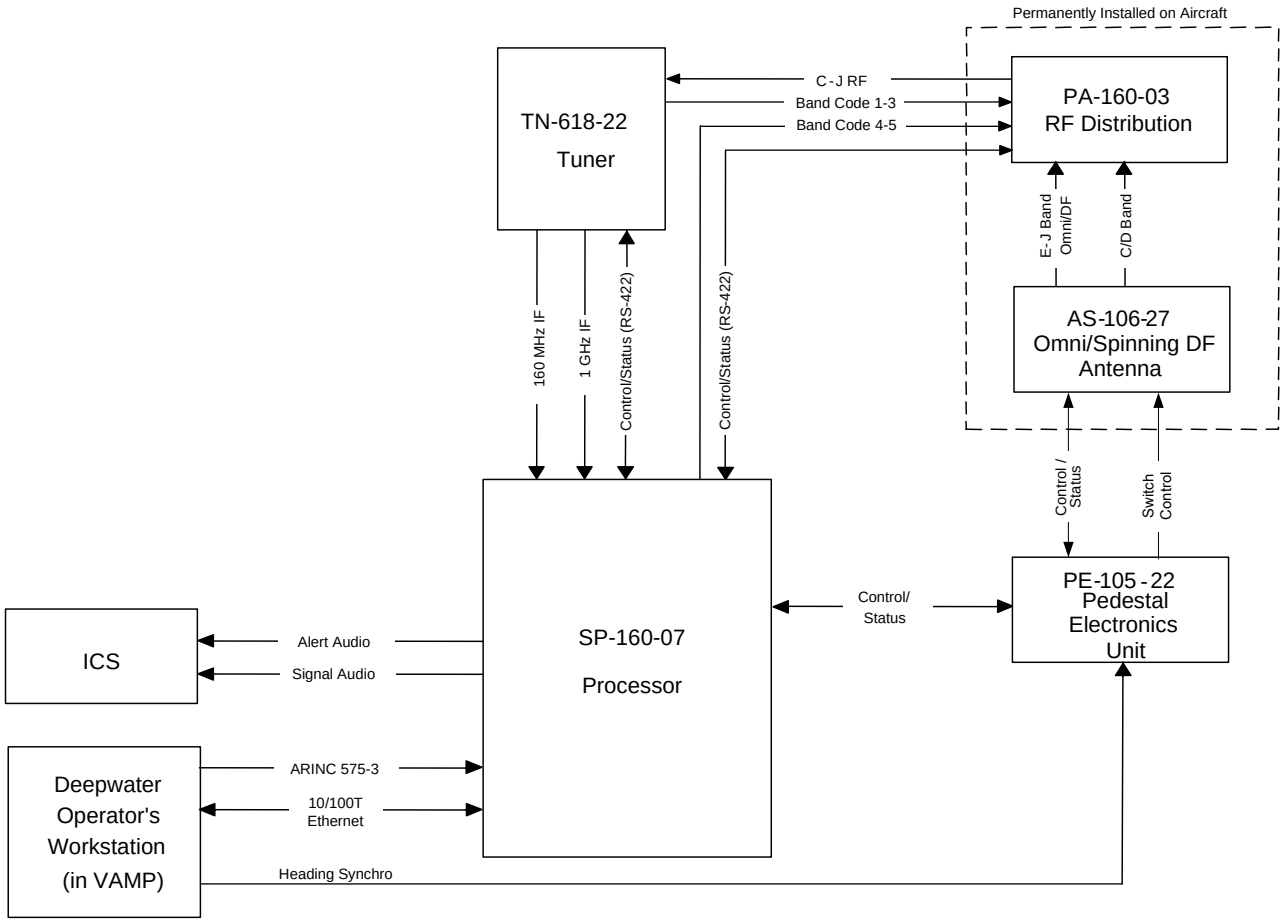
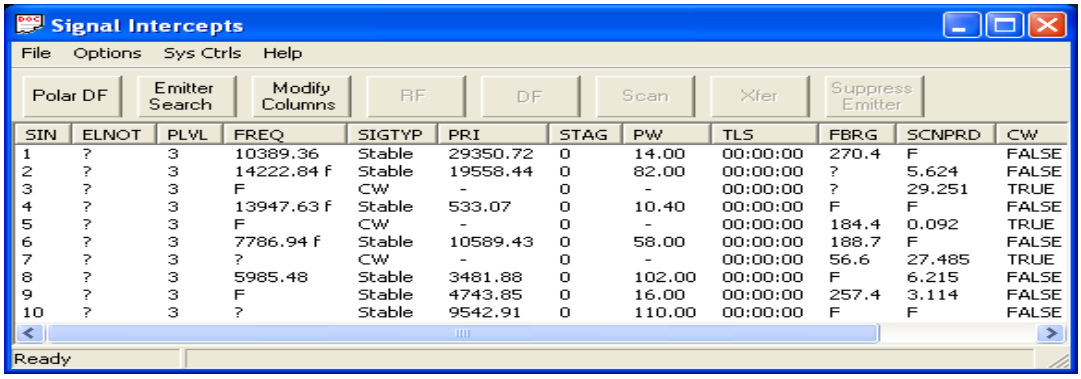


Figure 1: ALR-95 CASA Schematic

which delineates what parts are permanently installed and what information is passed between components. Having the system palletized allows for “roll-on role-off” mission flexibility. The components of the system that are on the pallet are the TN-618-22 Microwave Tuner, the SP-160-07 Signal processor (including the new DXP-213 SEI processor) and the PE-105-22 Pedestal Electronics Unit.

User Interface

The GUI used by the operator is run by MATLAB and is compatible with Windows. Figure 2 shows one of the windows available to the operator. The operator can use this window



SIN	ELNOT	PLVL	FREQ	SIGTYP	PRI	STAG	PW	TLS	FBRG	SCNPRD	CW
1	?	3	10389.36	Stable	29350.72	0	14.00	00:00:00	270.4	F	FALSE
2	?	3	14222.84 f	Stable	19558.44	0	82.00	00:00:00	?	5.624	FALSE
3	?	3	F	CW	-	0	-	00:00:00	?	29.251	TRUE
4	?	3	13947.63 f	Stable	533.07	0	10.40	00:00:00	F	F	FALSE
5	?	3	F	CW	-	0	-	00:00:00	184.4	0.092	TRUE
6	?	3	7786.94 f	Stable	10589.43	0	58.00	00:00:00	188.7	F	FALSE
7	?	3	?	CW	-	0	-	00:00:00	56.6	27.485	TRUE
8	?	3	5985.48	Stable	3481.88	0	102.00	00:00:00	F	6.215	FALSE
9	?	3	F	Stable	4743.85	0	16.00	00:00:00	257.4	3.114	FALSE
10	?	3	?	Stable	9542.91	0	110.00	00:00:00	F	F	FALSE

Figure 2: Signal Intercepts Display

to see the various incoming signals which are found by the spinning DF antenna over the C through J bands. IIP is interested in S and X bands and these are detectable by the ALR-95(V). An initial frequency can be seen (FREQ) and then a fine bearing can be found by focusing the DF antenna on one signal (FBER). These precision line bearings to the emitter can be taken as the airframe flies overhead and then combined to show the location (latitude and longitude) of the emitter.

As the aircraft turns to gather bearings, the antenna needs to be manually rotated towards the emitting signal. Figure 3 shows the screen used by the operator to control the antenna direction. The bottom part of the figure shows the frequency spectrum being collected.

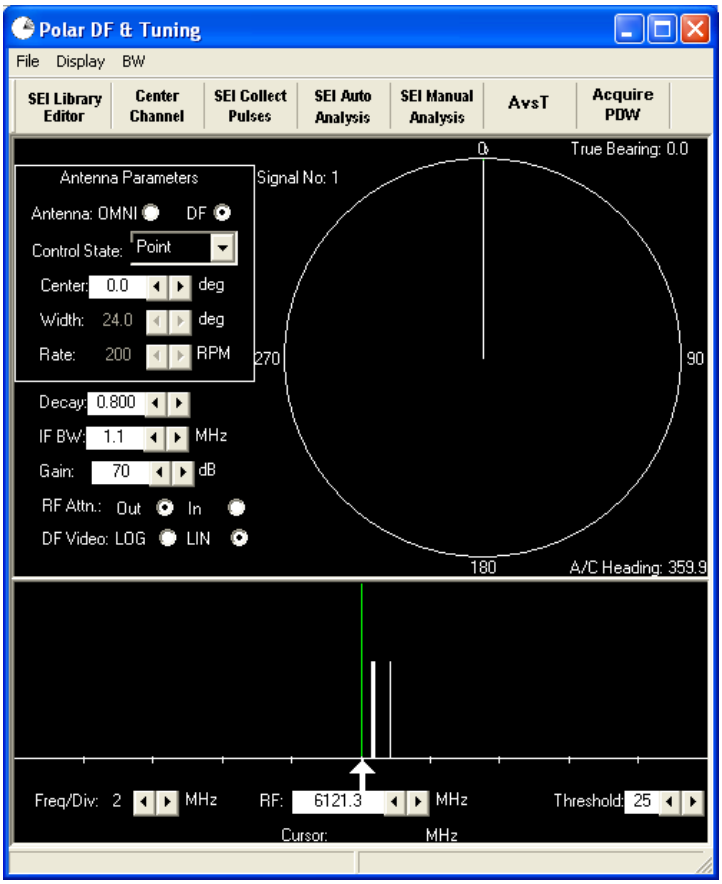


Figure 3: Antenna Control

Specific Emitter Identification (SEI)

The ALR-95 has SEI capability. As the signals seen in Figure 2 are collected, the signals can be compared to a library data base to specifically identify the type of emitter as seen in the GUI in Figure 4. The operator must compare the signal to an uploaded library saved internally on

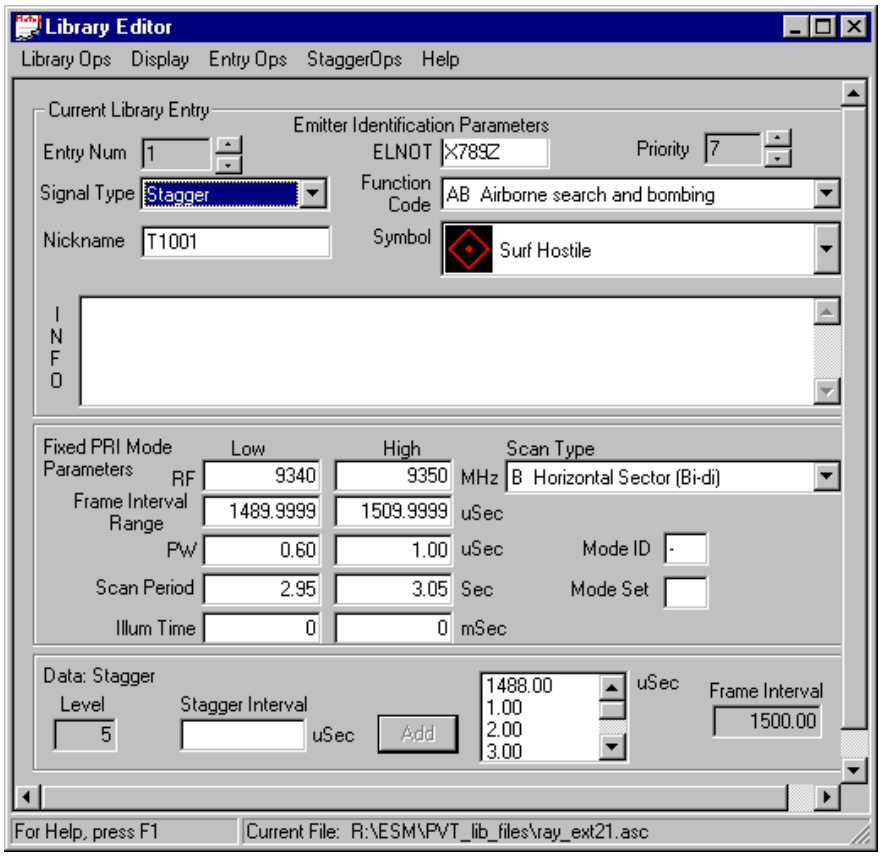


Figure 4: Library Function GUI

the workstation. The operator can also save new signals to the library for known emitters and then submit them to the national library. There are specific requirements that must be followed to enter an emitter into a library which includes several photographs from different angles of the vessel, the vessel name, and other amplifying information.

Design Decisions:

Three designs were found to potentially meet the needs of IIP: the ALR-95(V), a Canadian system and the ALR-66B(V)3. The decision was made to pursue the ALR-95(V) over the other two systems for the reasons below.

The Canadian system was a top secret project controlled by the Canadian government. When one researcher was asked about the system, the only information available was a lab report on the system and a few pictures. The system appeared to not be completed and tested. The inability to access any more information on the system forced the researchers to not consider this system at this time. In the future, the US and Canada should share technology in this area especially since the purpose of this system would be for a joint IIP operation.

The second and third systems were discovered by talking to the US Navy. They had a radar direction finding system called the ALR-66B(V)3. The Navy has used the ALR-66B(V)3 in the past and the functions are similar to that of the ALR-95(V). Currently the ALR-66B(V)3 is in the process of being updated in the Navy to the ALR-95(V). The Navy is keeping the direction finding portion of the ALR-66B(V)3's, so gaining their old systems was not an option. Obtaining old technology would be a good option if such systems were available. The ALR-66B(V) is old technology, and the military tends to keep equipment for many years past its life expectancy, so choosing an already antiquated system would not be the optimal decision.

The ALR-95 is already being installed on the CG CASA, so the processes will already be in place for maintenance, training, manufacturer contacts, and general familiarity. Over the course of the system's life, it will be easier for the CG to sustain the same system on both the CASA as well as the C-130J. The CG has limited resources, so keeping with a system that is already in place yet still meets (and actually exceeds with the SEI capability) the requirements would be beneficial.

Requirements:

Functional Requirement	Justification
Functionality	
System will have a visual interface with a geo-position for surface contacts which is usable by a trained operator.	This has been partially met because the interface of the ALR-95(V) has a windows GUI and the system is already used in the ALR-95(V). The system interface isn't as user friendly as hoped, however training can be used to increase effectiveness.
Detect X-band and S-band radar signals.	This has been met.
Operable at altitudes of 5500 to 8000 ft.	This has been met.
System must be attainable and testable.	This has been met because the ALR-95(V) has been tested.
Performance	
Operable at altitudes of 5500 to 8000 ft.	This has been tested but not analyzed.

APPENDIX I: Cost E-mails

Iceberg Differentiation

COST E-MAILS

May 1st, 2008

By: Abigail Lafond & Bryan Weber

From: Rothberg, Rhett R.
Sent: Tuesday, February 26, 2008 11:17 AM
To: McIntire, Ronald
Cc: Seitz, Richard; Lafond, Abigail Cadet; Weber, Bryan Cadet
Subject: RE: Cost of ALR-95 on J model

Ron,

Yes, actually, the International Ice Patrol (IIP) uses AIS during their patrols. However, there are from time to time fishing vessels not equipped with AIS that do not respond to hails on VHF. So the only way for the IIP to identify a target as a vessel or iceberg in a low vis environment is to divert from track and dive down to a low ceiling.

The hope is that the ALR-95 could help reduce these somewhat costly diverts.

We'll take anything you have on support.

Thanks!!

v/r
LT Rhett Rothberg
From: McIntire, Ronald [mailto:Ronald.McIntire@dwicgs.com]
Sent: Tuesday, February 26, 2008 10:50 AM
To: Rothberg, Rhett R.
Cc: Seitz, Richard; Lafond, Abigail Cadet; Weber, Bryan Cadet
Subject: RE: Cost of ALR-95 on J model

Have you considered an alternative equipment or device to fulfill this mission need? The reason I ask is that it sounds like the Saab R-4A Automatic Identification System (AIS) may fit the bill…

As far as a ROM for tech support, I don't have anything in writing, only verbal. Phone tech support was estimated to be ~$165/ hr; on-site is that plus travel and per diem. Again, ARSC is working to put time and materials contracts in place, so that tech support can be used on an as-needed basis.

Hope this helps, V/R, Ron

Ron McIntire, CG-9312
HC-144A Project Manager
USCG Aviation Acquisition CG-931
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"Acquisitions and contractual commitments can only be made by Government officials having expressed authority to enter into such agreements on behalf of the United States Government. The ONLY Government officials with such authority are Warranted Contracting Officers. I am NOT a Warranted Contracting Officer. Any discussions of contractual requirements do not constitute contractual direction or authorization of any kind. Future contractual direction, IF ANY, shall ONLY come from the cognizant Coast Guard Deepwater Warranted Contracting Officer."

From: Rothberg, Rhett R. [mailto:Rhett.R.Rothberg@uscga.edu]
Sent: Tuesday, February 26, 2008 10:32 AM
To: McIntire, Ronald
Cc: Seitz, Richard; Lafond, Abigail Cadet; Weber, Bryan Cadet
Subject: RE: Cost of ALR-95 on J model

Mr. McIntire,

This is just what we were looking for.

We are researching the ALR-95 as a tool for the International Ice Patrol. They do not need the SEI capability of the ALR-95. Rather, all they need is the direction finding capability. That way they can distinguish vessels with active radar from icebergs at a large distance.

I think that capability, which I hope does not require the same operator expertise, is a pretty useful one.

If you do also have a ROM type estimate for support as well, that would be very useful to us as well.

Thanks again for your help!

v/r
LT Rhett Rothberg
From: McIntire, Ronald [mailto:Ronald.McIntire@dwicgs.com]
Sent: Tuesday, February 26, 2008 7:07 AM
To: Rothberg, Rhett R.
Cc: Seitz, Richard; Lafond, Abigail Cadet; Weber, Bryan Cadet
Subject: RE: Cost of ALR-95 on J model

Hi All,

Let me send this before the day gets rolling and I'll see what else I can provide. One of my concerns with the ALR-95 has been training- Navy operators have a six month school that they attend, and when they're flying in the P-3's, that's their only job. As you're aware SEI is only one of the sensors aboard the Ocean Sentry, so I asked that the OEM provide some rudimentary training.

Attached is an estimate from EDO (now ITT) on providing a training class. I've also sent funding to ARSC to establish contractor support for various systems aboard the aircraft but don't know the status; I know they're working to establish a time & materials support contract.

I don't have access to the C-130J files on the IPDE, so I can't provide you the BCA that Rick mentioned.

Hope this helps, Ron

Ron McIntire, CG-9312
HC-144A Project Manager
USCG Aviation Acquisition CG-931
(V) 571.227.9918
(C) 571.243.5029
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From: Rothberg, Rhett R. [mailto:Rhett.R.Rothberg@uscga.edu]
Sent: Monday, February 25, 2008 9:37 PM
To: McIntire, Ronald
Cc: Seitz, Richard; Lafond, Abigail Cadet; Weber, Bryan Cadet
Subject: FW: Cost of ALR-95 on J model

Mr. McIntire,

I am the project advisor for Cadet's Lafond and Weber here at the US Coast Guard Academy.

I don't know that we need an estimate to a great level of detail.

We are researching the capability of the system mainly, but we could add some useful information to this report if we could include some cost figures as well.

Mr. Rick Seitz (copied on this email) had sent us the following:

From: Seitz, Richard [mailto:Richard.Seitz@dwicgs.com]
Sent: Wednesday, February 20, 2008 12:43 PM
To: Schron, David; Lafond, Abigail Cadet
Subject: RE: Cost of ALR-95 on J model

CWO Schron, 1/C Lafond,

The C-130J Operational Requirements Document established a requirement for ESM/SEI. As part of the Lockheed Martin business case analysis, LM evaluated the cost of installing an ALR-95 to fill the requirement.
Cost for installing ALR-95 and incorporating it into the C-130J Mission System on all six aircraft came to approximately $17M. Unfortunately, I don't any more specific information. Hope this helps.

Thanks
rick

Rick Seitz
C-130 Projects Manager
CG-931, Aviation Acquisition
571-227-6797

This is about the level of detail we are interested in, just overall estimates of installation cost and perhaps an estimate of support.

Would it be possible to get a copy of the Lockheed Martin business case referenced above?

Thanks again to you and Mr. Seitz for helping us out with this. It is greatly appreciated!!

v/r
LT Rhett Rothberg

US Coast Guard Academy

From: Lafond, Abigail Cadet
Sent: Tuesday, February 19, 2008 2:52 PM
To: Rothberg, Rhett R.
Subject: FW: Cost of ALR-95 on J model

LT Rothberg Sir,

I respectfully request to inform you that I have received the following information, but what does it mean exactly? I will be right over if that it ok.

Very respectfully,
1/c Abbey Lafond

From: McIntire, Ronald [mailto:Ronald.McIntire@dwicgs.com]
Sent: Tuesday, February 19, 2008 2:41 PM
To: Schron, David; Polaski, Gary
Cc: Lafond, Abigail Cadet
Subject: Re: Cost of ALR-95 on J model

Sir, we may be able to come up with a figure, but it will have to be broken down into recurring (the system hardware, also known as the "B" kit, the cables and accessories, also known as the "A" kit, any software mods to the Operational Flight Program, and the labor to perform the integration) and the non-recurring engineering costs (NRE), such as drawing changes, airworthiness certs, flight testing, etc.

What makes a project like this a challenge is that I'd probably have to give you three answers- dependant upon who does the work. It will have to be broken down as organic (ARSC), contracted out to a prime (like Lockheed), or given to an outside Gov't agency (NAVAIR).

We can get the HW costs fairly quickly, and I believe we're on a path to have the LRS and MRS have the same SW load- they descoped SIPRNET, but we've already written the code for the ESM. Anything we provide would be predicated on the assumption that the LRS would use an identical system to the MRS.

How quickly do the folks need the answer? My plate is pretty full trying to get through. DT and award 9-12 and pallets-- let me know and I'll see what we can do.

V/R, Ron

Sent from my Blackberry wireless handheld

----- Original Message -----
From: Schron, David
To: McIntire, Ronald; Polaski, Gary
Cc: Abigail.S.Lafond@uscga.edu <Abigail.S.Lafond@uscga.edu>
Sent: Tue Feb 19 14:15:36 2008
Subject: FW: Cost of ALR-95 on J model

Mr. McIntire, LCDR Polaski

Can you shed any light on Cadet 1/c Lafond's question below? I realize none of us are qualified to answer how much it would cost to install the ALR 95 on a C 130 but perhaps you can shed light on the cost to install on the MRS.

Thanks!

CWO David Schron
USCG CG-933 C4ISR
Systems Integration Program Office
1530 Wilson Blvd
Arlington, VA 22209
Office: 571-227-6837
Cell: 571-217-9748
David.Schron@dwicgs.com

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-----Original Message-----
From: David.F.Schron@uscg.mil [mailto:David.F.Schron@uscg.mil]
Sent: Tuesday, February 19, 2008 12:02 PM
To: Schron, David
Subject: FW: Cost of ALR-95 on J model

-----Original Message-----
From: Abigail.S.Lafond@uscga.edu [mailto:Abigail.S.Lafond@uscga.edu]
Sent: Thursday, February 14, 2008 10:55 AM
To: Schron, David AVI2
Cc: Rothberg, Rhett R.; Weber, Bryan Cadet
Subject: Cost of ALR-95 on J model

AVI2 Schron,

My name is Abbey Lafond and I am a senior at the Coast Guard Academy. For my senior project, I'm working with the ALR-95, and I understand you may have some expertise in the area. My partner (Bryan Weber) along with our project advisor (LT Rothberg) and I are working with the International Ice Patrol to hopefully get the ALR-95 installed on the C-130J airplane in the future. I was wondering if you had any information regarding how much it would cost to place the system on the aircraft. I understand that we were looking into using the system on the J model under deepwater, but that the cost was too high. Do you have the cost analysis? If not do you know who does? Any information you can give us would be greatly appreciated. Thank you for your assistance and have a great day.

Very respectfully,

1/c Abbey Lafond

APPENDIX J: ALR-95(V) Sensitivity Specifications

Iceberg Differentiation

ALR-95(V) Sensitivity Specifications

May 2nd, 2008

By: Abigail Lafond & Bryan Weber

Data acquired from ITT Corporation; contact:
K.C. Coggins, Business Development Manager
Voice 408-310-2835
Fax 408-201-7810
kenneth.coggins@edocorp.com

Receiver Sensitivity @ 10GHz = -65 dBm
Assume Receiver Sensitivity is flat across passband
Assume 3 dB RF interconnect cable loss between antenna and Reciever
Assume 1 dB Radome Loss
System Sensitivity s/b Receiver Sensitivity + gain - cable loss - Radome Loss

DF @ 10GHz = -65 - 22 + 3 +1	-83 dBm
Omni @ 10GHz = -65 -1 +3 +1	-62 dBm

Antenna Gains v Frequency

Frequency	Gain
	Low Band DF
0.5 GHz	-7.0 dBic
0.75 GHz	-3.0 dBic
1.0 GHz	-1.5 dBic
1.5 GHz	1.0 dBic
2.0 GHz	3.0 dBic
	High Band DF
2 GHz	7.0 dBi
4 GHz	15.0 dBi
6 GHz	17.0 dBi
8 GHz	20.0 dBi
10 GHz	22.0 dBi
12 GHz	22.0 dBi
14 GHz	22.0 dBi
16 GHz	22.0 dBi
18 GHz	24.0 dBi
	High Band Omni
2 GHz	-14.0 dBi
4 GHz	-5.0 dBi
6 GHz	-4.0 dBi
8 GHz	0.0 dBi
10 GHz	1.0 dBi
12 GHz	1.0 dBi
14 GHz	1.0 dBi
16 GHz	1.0 dBi

18 GHz	2.0 dBi